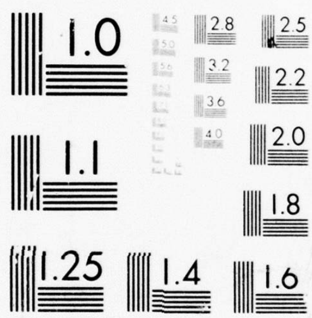
AD-A048 203 SCS ENGINEERS LONG BEACH CALIF F/G 13/2
FEASIBILITY OF INLAND DISPOSAL OF DEWATERED DREDGED MATERIAL: A--ETC(U)
NOV 77 DACW39-76-C-0121

UNCLASSIFIED WES-TR-D-77-33 NL

1 OF 2
AD
A048203



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12)

FG.

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-33

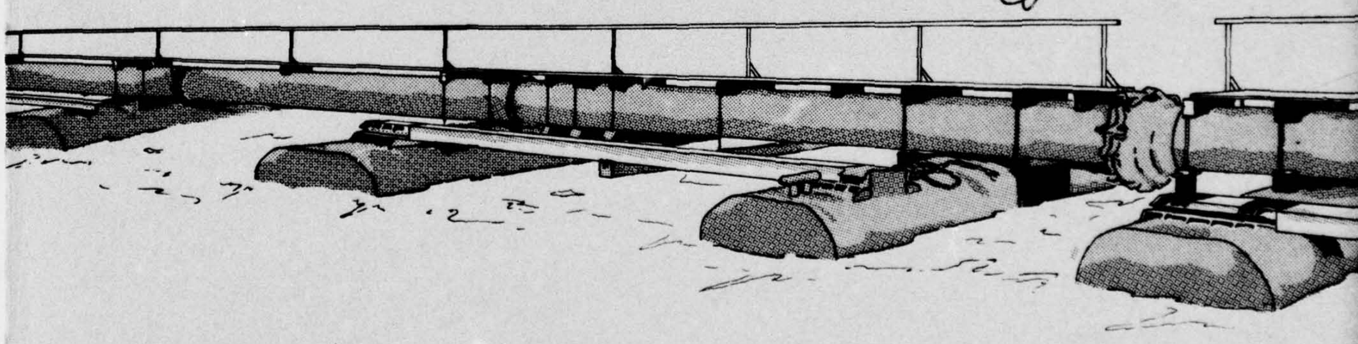
FEASIBILITY OF INLAND DISPOSAL OF DEWATERED DREDGED MATERIAL: A LITERATURE REVIEW

by

SCS Engineers
4014 Long Beach Blvd.
Long Beach, Calif. 90807

November 1977
Final Report

Approved For Public Release; Distribution Unlimited



Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW39-76-C-0121
(DMRP Work Unit No. 3B02)

Monitored by Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

Destroy this report when no longer needed. Do not return it to the originator.

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION. CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG. MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

28 November 1977

SUBJECT: Transmittal of Technical Report D-77-33

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of several research efforts (work units) undertaken as part of Task 3B, Upland Disposal Concept Development, of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 3B, part of the Productive Uses Project (PUP), has a general objective of determining the feasibility of inland disposal of dewatered dredged material.

2. Because of possible constraints on open-water disposal of dredged material, the Corps of Engineers has had to resort more and more to land disposal. In the past, land disposal sites have been located close to the dredging project, primarily to minimize material transport costs, afford easy access by water, and allow effluent to return to the waterway. However, location of new land disposal areas near the dredging project is presently being limited by environmental and land-use constraints. Consequently, one objective of this study was to assess the technical feasibility of inland disposal of dewatered dredged material.

3. Since very few inland disposal areas presently exist, feasibility was determined by a complete information survey of relevant information sources. Literature on practices in solid waste and sewage sludge disposal coupled with information from the Corps of Engineers, the Environmental Protection Agency, other Federal and State agencies, port authorities, and private organizations and universities known to be conducting research on dredged material disposal was used as the primary input for determining feasibility.

4. Overall, literature sources and personnel interviews indicate that an inland dredged material disposal site can be operated in a manner that is environmentally sound and is socially compatible with its surroundings, especially when the material is relatively uncontaminated. On the other hand, land disposal of contaminated dredged material warrants special attention. Depending on the contaminant content, the local climate, the disposal method used, and the characteristics of the disposal area, contaminated dredged material can be a source of contaminated leachate, odor, dust, vermin attraction, and other adverse environmental impacts. Proper site selection, design, and operation can

adequately protect the environment in the vicinity of the disposal site. It appears that solid waste disposal technology can be adapted to the disposal of contaminated dredged material.

5. An additional objective of this study was to summarize the information and present it in a checklist format to facilitate direct use by decision-makers and agencies faced with the responsibility of locating and operating inland disposal sites. Use of the checklist can assist officials in several basic tasks: site location, selection, and preparation and the evaluation of disposal operations. The checklist is designed for a worst-case situation in which the dredged material is highly contaminated; the list covers all possible factors that must be evaluated in selecting an environmentally and socially acceptable disposal site.

6. The report also points out that dredged material is a soil resource rather than a waste material and offers potential reuse value. When properly disposed, dredged material can be an asset to an area. A completed disposal site offers an ideal opportunity to enhance land for permanent beneficial purposes, and, depending on the type of material deposited, the site can be used for recreational, urban, and/or industrial development.

John L. Cannon
JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

18 WES 19 TR-D-77-33

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Technical Report D-77-33

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 FEASIBILITY OF INLAND DISPOSAL OF DEWATERED DREDGED MATERIAL: A LITERATURE REVIEW.

5. TYPE OF REPORT & PERIOD COVERED
9 Final rep[redacted]t.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)
Contract No. NEW
15 DACW39-76-C-0121

9. PERFORMING ORGANIZATION NAME AND ADDRESS
SCS Engineers
4014 Long Beach Blvd.
Long Beach, California 90807

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
DMRP Work Unit No. 3B02

11. CONTROLLING OFFICE NAME AND ADDRESS
Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

12. REPORT DATE
11 Nov[redacted]77

13. NUMBER OF PAGES
153 12 160p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
U. S. Army Engineer Waterways Experiment Station
Environmental Effects Laboratory
P. O. Box 631, Vicksburg, Mississippi 39180

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

390 741

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dewatering	Inland disposal sites
Disposal areas	Site selection
Dredged material disposal	Solid wastes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results from an investigation of the feasibility of inland disposal of dewatered dredged material. The engineering, economic, social, and institutional factors associated with this method are identified and summarized in the report. The study is basically a thorough literature review of municipal and industrial solid waste management practices supplemented with specific information on dredged material.

(Continued)

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

A comprehensive checklist is included that is meant to be used as a decision-making tool by officials who must provide inland sites for the final disposal of dredged material. The checklist presents a step-by-step planning process for site selection and final site use. The planning process considers all factors necessary to provide a cost-effective disposal site which meets the requirement of being environmentally compatible with its surroundings.

The primary findings are that inland disposal of dredged material is feasible and that the sites can be designed and operated in a manner which is environmentally sound and socially compatible. However, minor operational problems may be encountered which can only be identified following some field testing of the criteria. Also, there is as yet insufficient data available concerning the quality and quantity of leachate expected from land-deposited dredged material to enable an accurate engineering design of control systems.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

EXECUTIVE SUMMARY

The purpose of this study was to assess the feasibility of inland disposal of dewatered dredged material. Inland disposal is here defined to be the disposal of dredged material at sites which are inland from the dredging project. The engineering, environmental, economic, social, and institutional factors associated with this method of disposal were identified from various information sources and are summarized in the report.

A checklist supplements the data summary and is meant to be used as a decision-making tool by officials who must provide inland sites for the final disposal of polluted dredged material, and by officials who are required by State and/or local agencies to develop a site plan or who must meet specific end use requirements. This checklist presents a step-by-step planning process for site selection and final site use. The planning process considers all factors necessary to provide a cost-effective disposal site that is environmentally and socially compatible with its surroundings.

Data on dredged material disposal activities were obtained from the Dredged Material Research Program (DMRP); Corps of Engineers Districts; Department of the Army, Office, Chief of Engineers; U.S. Environmental Protection Agency (EPA); Naval Facilities Activities Command (NAVFAC); various State environmental regulatory agencies and port authorities; and organizations and universities studying dredged material disposal. A thorough review of literature regarding municipal and industrial solid waste management supplemented specific information sources on dredged material. The limitations of applying solid waste management data to dredged material disposal must be recognized and are noted where applicable.

Dredged material is a soil resource rather than a waste material and offers potential reuse value. When properly disposed, dredged material can be an asset to an area. A completed disposal site offers an ideal opportunity to enhance land for permanent

beneficial purposes. Depending on the type of material deposited, the site can be used for recreational, urban, and/or industrial development.

Public opposition to an inland disposal site may arise from the physical and social aspects of site location. Further opposition may stem from the potential environmental problems caused by transportation and disposal of the material. Depending on the pollutant content of the dredged material, the local climate, the disposal method used, the characteristics of the disposal area, and the transportation method, dredged material may be a source of adverse environmental impacts. However, proper site selection, design, and operation can adequately protect the environment in the vicinity of the site.

Regulatory agencies in many localities may control the selection of inland dredged material disposal sites and subsequent material placement. State, local, and Federal agencies with jurisdiction over waste disposal, water-quality protection, zoning, and other environmental issues should be consulted for laws and policies on land disposal activities concerning a specific dredged material disposal plan.

Development costs for an inland dredged material disposal site include capital, operating, environmental protection, and transportation costs. These costs are site specific and depend on the volume of dredged material to be disposed, method of transportation, need for access road construction, types of equipment used on-site, site topography, prevailing labor wage rates, and land costs. The area's hydrogeological features will largely influence the degree and hence the cost of water-quality monitoring facilities needed.

Overall, literature sources and personal interviews indicate that an inland dredged material disposal site can be designed and operated in a manner which is environmentally sound and is socially compatible with its surroundings. However, there is as yet insufficient data available concerning the quality and quantity of leachate expected from land-deposited dredged material on which to base an accurate engineering design of control systems. Also, minor operational problems may be encountered which can only be identified following close evaluation of a controlled inland disposal site.

Consequently, it is recommended that the current DMRP research on leachate production continue and that a detailed case study be conducted of an operational inland disposal site.

PREFACE

The work reported herein was performed under Contract DACW 39-76-C-0121 entitled, "Feasibility of Inland Disposal of Dredged Material: A Literature Review," dated June 28, 1976, between the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, and SCS Engineers, Long Beach, California. The research was sponsored by the Dredged Material Research Program, which is administered by the Environmental Effects Laboratory, WES. The study was conducted under Task 3B of the DMRP, "Upland Disposal Concepts Development."

The report summarizes information on all factors affecting dredged material disposal in inland areas. A checklist was formulated from this information to be used by decision makers for selecting potential disposal sites.

The research was conducted under the supervision of Mr. Robert P. Stearns, P.E., Principal, SCS Engineers. Messrs. David E. Ross, P.E., Associate, and Larry K. Barker served as Project Managers. Research, interviews, and reporting were performed by Ms. Inda Taylor and Mr. Donald Sherman. Editorial assistance was provided by Ms. Kitten Borgers and clerical support by Ms. Lona Taylor, Ms. Cynthia DeVore, and Mrs. Ramona Preston.

The report was prepared under the general supervision of the manager of the Productive Uses Project (PUP), Mr. Thomas R. Patin. Dr. Roger Saucier and MAJ Robert M. Meccia were also managers of PUP during the research phase of the project. Dr. John Harrison was Chief of the Environmental Effects Laboratory, WES. Directors of WES during the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
mils	0.0254	millimetres
inches	25.4	millimetres
feet	0.3048	metres
yards	0.9144	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square yards	0.8361274	square metres
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
gallons (U. S. liquid)	3.785412	cubic decimetres
pounds (mass)	0.4535924	kilograms
tons (2000 pounds mass)	907.1847	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
horsepower	745.6999	watts

FEASIBILITY OF INLAND DISPOSAL OF DEWATERED DREDGED MATERIAL: A LITERATURE REVIEW

PART I: INTRODUCTION

Report Organization

1. The information compiled for this report is presented in three sections:

- Part I - Introduction.
- Part II - Summary of Information on Inland Disposal of Dredged Material.
- Part III - Disposal Site Selection Checklist.

2. Part II is divided into chapters and presents a summary of available information pertinent to inland disposal of dredged material. Also included in Part II is a discussion of apparent deficiencies in current practices and needs for further research.

3. Part III incorporates and summarizes the data in Part II into a comprehensive checklist to be used by decision makers as a basis for determining potential inland disposal sites. The checklist is in a form suitable for reproduction and field use. Instructions and recommendations for its use are included.

Background

4. The major emphasis of past research under the DMRP has been directed toward defining the methodology and environmental impacts associated with open-water disposal of dredged material. Despite recent reports (Lee and Plumb 1974; Lee et al. 1975; and Chen et al. 1976) which indicate that the release of soluble contaminants during open-water disposal operations is minimal in most cases, open-water disposal practice has been drastically reduced due to passage and strict enforcement of water-quality legislation. Consequently, the Corps of Engineers (CE) is relying more on the practice of disposing of dredged material on land, often at sites inland from the dredging project.

5. Most inland disposal sites have been located close to the dredging project primarily to minimize material transport costs, to afford easy access by water, and to allow effluent to return to the

waterway. However, location of new land disposal areas near the dredging project is being limited due to environmental and land use constraints. Increasing public awareness of fragile wetland's ecology has spawned legislation in some states to control further filling of marsh and low-lying areas, landforms that are typically adjacent to dredging projects. Prime recreation and industrial lands associated with these wetlands fulfill most of the remaining land uses in a project area. Consequently, research is underway within the DMRP to investigate inland disposal operations. Inland areas as defined for this study include those areas located at a distance from the dredging project and out of the coastal, riverine, and lacustrine zones. Thus, an inland dredged material disposal site could be a few hundred yards from the dredging project or hundreds of miles inland.

6. For this study, it has been assumed that only dewatered dredged material would be suitable for transport to an inland disposal site. The characteristics of this material, further discussed in Chapter 1 of Part II, determine the transportation mode, disposal site characteristics required, site operation methods, and final site use.

Purpose and Scope of Research and Checklist

7. The purpose of this study was to assess the feasibility of inland disposal of dewatered dredged material. The engineering, environmental, economic, social, and institutional factors associated with this method of disposal were identified from various information sources and are summarized in the report. The summarized information is also presented in a checklist format to facilitate direct use by decision makers and agencies faced with the responsibility of locating and operating inland disposal sites.

Approach

8. An information search was initiated for this project. Various sources were identified by WES personnel and from published

research. Investigations of land disposal activities were conducted in several Corps District Offices. All established inland disposal sites were documented through telephone contact and interviews with District personnel. Thorough investigations including field visits to land disposal activities were conducted in the following CE Districts: Baltimore, Jacksonville, Mobile, Philadelphia, Portland, and Sacramento. Other data sources, which included the following Federal and State agencies, were explored: Department of the Army, Office, Chief of Engineers; U.S. Environmental Protection Agency (EPA); various regions of the Naval Facilities Activities Command (NAVFAC); various State environmental regulatory agencies; and several port authorities. Private organizations and universities known to be conducting research on dredged material disposal were also contacted.

9. Currently available information specifically concerning dredged material provides an inadequate basis for evaluating the feasibility of inland disposal. Historically, very little attention has been given to this disposal method. However, methods for land disposal of dredged material can be adapted from disposal practices already developed for solid waste and sewage sludge. Much information has been gathered about the engineering, environmental, economic, social, and institutional factors affecting disposal practices of these wastes which have been deposited on land for many years.

10. Dredged material is a valuable resource, and when properly disposed, it offers an ideal opportunity to enhance land for permanent beneficial purposes. Solid waste disposal technology can be a useful guide for the proper design and operation of a dredged material disposal site that meets final end use specifications. State and local agencies with jurisdiction over land disposal activities may require that a site plan be developed which can readily be formulated from present available solid waste disposal technology.

11. Land disposal of polluted dredged material warrants special attention. Depending on the pollutant content, the local climate, the disposal method used, and the characteristics of the disposal area,

polluted dredged material can be a source of leachate, odor, dust, vermin attraction, and other adverse environmental impacts. Proper site selection, design, and operation can adequately protect the environment in the vicinity of the disposal site. Solid waste disposal technology can be a foundation for the proper disposal of polluted dredged material. However, limitations of such technology should be recognized at all times and will be noted wherever pertinent in this report.

Intended Audience and Checklist Uses

12. All sponsors of dredging projects who must provide a disposal site for the material should find the summary report and checklist useful. This group includes representatives of the CE; NAVFAC, which conducts dredging activities similar to that of the CE; port authorities; and other Federal, State, and local decision makers.

13. Use of the checklist can assist officials in several basic tasks:

- Site location.
- Site selection.
- Site preparation.
- Evaluation of disposal operations.

The checklist provides a rational means for selecting an environmentally acceptable, cost-effective dredged material disposal site that meets project needs or substantiates the lack of adequate disposal areas.

PART II: SUMMARY OF INFORMATION ON INLAND DISPOSAL OF DREDGED MATERIAL

PrecedING Page BLANK - NOT FILMed

CHAPTER 1: CHARACTERISTICS OF DREDGED MATERIAL

14. Dredged material varies greatly in its physical and chemical characteristics depending on geographical location of the dredging project, the type of dredging equipment, and whether the material is from new work or maintenance operations.

15. Dredged material is the accumulation of detached soil particles which have been transported through the environment by wind, gravity, and ultimately hydrologic systems. As a soil, it is a resource with potential beneficial use. However, from its position in the transport cycle, dredged material may contain almost every chemical contributed to the environment by nature or man's activities.

16. The ability of dredged material to adsorb these chemicals is dependent on its soil makeup and the chemical availability. Particle size distribution plays an important role in the sorption reaction controlling the exchange of chemicals. The clay fraction is known to be the most important size fraction for sorption-desorption reactions (Khalid et al. 1977). The soil particle distribution of dredged material can range from rock to fine clay and mixtures thereof; hence, not all dredged material is capable of adsorption processes, and thus not all dredged material can be considered polluted.

17. Polluted dredged material in the United States is largely from industrial areas and may contain high concentrations of toxic chemicals from industrial effluents. In addition, high concentrations of nutrients ($PO_4^{=}$, NH_3^{+}, NO_3^{-}, etc.) and pesticides may be added to the system from a wide variety of sources, including agricultural runoff and municipal sewage discharges. High saline concentrations are also common because a large percentage of dredged material originates or is dredged from estuarine or marine waters. (Harrison and Chisholm 1974 and Lee et al. 1976).

18. Results from research on the physical, engineering, and chemical properties of dredged material have been documented. The reader is referred to the cited literature for the details of these studies (Krizek et al. 1973, 1974; Krizek and Salem 1974;

Chen et al. 1976; Lee et al. 1976; Bartos 1977a; Gambrell et al. 1977; and Khalid et al. 1977).

19. Basic parameters characteristic of dewatered dredged material and significant to any inland disposal operation include:

1. Physical characteristics:
    a. Grain-size distribution.
    b. Permeability.
2. Moisture content.
3. Organic matter content.
4. Chemical constituents.

20. An analysis of the engineering properties of dewatered material was reported by Bartos (1977a). The study concluded that dewatered dredged material exhibits the properties of soils, and, therefore, dredged material behavior can reliably be predicted from consideration of the characteristics of similar soil types.

Physical Characteristics

21. Dredged material is composed of soil particles ranging in size from rock to fine clay. Coarse-grained materials dewater naturally if drainage is provided. Fine-grained materials, because of their high water-holding capacity, require extensive effort to dewater. Bartos (1977a) suggested that these materials be dewatered to a point where they exhibit satisfactory engineering properties. In the case of an inland disposal site, dredged material must be dewatered to an optimum moisture content to facilitate handling and transportation and to reduce the possibility of leachate formation.

22. The intended inland disposal area will be affected in various ways by the characteristics of the deposited material. The constituents associated with a sediment are subject to leaching and may result in subsequent ground and surface water contamination. The permeability and relative adsorption properties of the deposited material significantly influence leachate migration. Figures 1 (Phillips, Eng, and Nathwani 1976) and 2 (Stearns et al. 1976) show

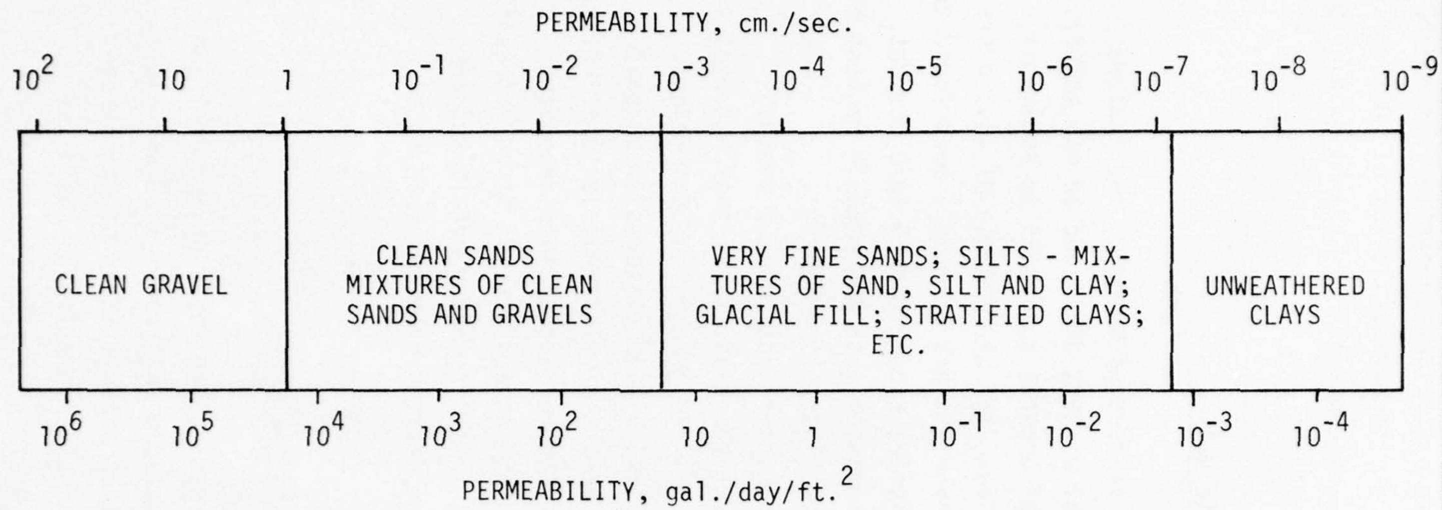


Figure 1. Range in permeability of different soil classes (Phillips, Eng, and Nathwani 1976)

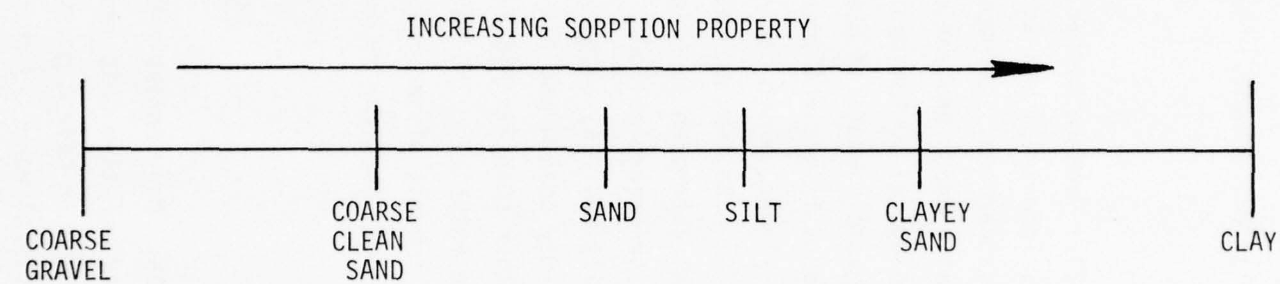


Figure 2. Sorptive properties of selected soils (Stearns et al. 1976)

the permeability rates and relative adsorption properties associated with the various soil types. Soils with permeabilities of 10^{-6} cm/sec or less would serve to inhibit leachate migration (Stearns et al. 1976 and Phillips, Eng, and Nathwani 1976).

Organic Matter

23. Organic matter present in dredged material may include sewage, industrial and agricultural wastes, plant and animal matter, and hydrocarbons. Decomposition of organic materials in sediments, especially under anaerobic conditions, may be a source of gas, odors, and biological contaminants. However, it has generally been found that the organic content of dredged material ranges from 4 to 8 percent. This range is insignificant when compared with the organic content of sewage sludge, which can range from 11 to 83 percent.

24. The texture and organic matter content of a dredged material determine to a large extent the capacity of that material to adsorb or desorb cations, anions, oil and grease, and pesticides. Fine silt and clay along with relatively high contents of organic matter may adsorb and fix a large amount of plant nutrients as well as many other constituents from water leached out of land-deposited dredged material. The cation exchange capacity (CEC) is an expression of the amounts of various cations, including heavy metals and some pesticides, that can be sorbed in a dredged material (Lee et al. 1976).

Chemical Constituents

25. Many contaminants are retained in soils by chemical and physical sorption onto the soil particle surfaces. Silt and clayey soils tend to have a greater sorptive capacity than sands. Krizek et al. (1974) reported that the leachate migration potential is a function of initial structure and grain-size distribution of the dredged material. The phenomenon of pore clogging will decrease

average permeability over a period of time due to leaching of some constituents, which will ultimately decrease leachate migration.

26. Current DMRP-sponsored research* on dredged material disposal on land shows that the chemical constituents of the material are tied up in the dredged material's soil matrix, and low levels of contaminants are released during dewatering or leaching processes. Ranges of the various constituents that can be expected in dredged material are presented in Table 1 (Chen et al. 1976).

27. Chen et al. (1976) reported that contaminants and nutrients in dredged material may be leached out under certain environmental conditions when disposed of in open waters. Greater amounts of some heavy metals and nutrients are released in a reducing (anaerobic) environment than in an oxidizing (aerobic) environment. Low pH and redox potential tend to favor the formation of soluble species of many metals. Under oxidized, high pH conditions, forms that are insoluble or only slightly soluble tend to predominate. There is also considerable evidence that the presence of sulfides is important in this respect. Where considerable sulfide is present, trace elements may be effectively immobilized in a reduced environment through sulfide precipitation. In the case of mercury, there is some evidence that sulfide may polymerize and form a soluble compound which contains a somewhat greater level of mercury than might otherwise be expected (Khalid et al. 1977). Characterization of the mobility and availability of chemical constituents in dredged material is currently under investigation in the DMRP.**

---

* From Personal Communication, December 9, 1976, Ronald Hoeppel, Research Microbiologist, U.S. Army Engineer Waterways Experiment Station.

** These investigations are being conducted under DMRP Work Units 2D05 (University of Southern California, Los Angeles), 2D02 (SCS Engineers, Long Beach, California), and 2D01 (Environmental Effects Laboratory, WES).

Table 1

Concentrations of Chemical Constituents of Dredged Materials

(Chen et al. 1976)

Constituent	Range expected in concentration (mg/kg)
Chemical Oxygen Demand, COD	1.0 - 13%
Total Organic Carbon, TOC	0.5 - 5%
pH	6 - 9
Total Sulfides (acid soluble)	100 - 3,000
Oil and Grease	100 - 5,000
Organic Nitrogen	100 - 2,000
Ammonia, NH_4-N	100 - 2,000
Total Nitrogen	200 - 4,000
Total Phosphorus	500 - 2,000
Calcium, Ca	600 - 17,000
Chloride, Cl	40 - 20,000
Magnesium, Mg	4,000 - 13,000
Potassium, K	17,000 - 24,000
Sodium, Na	12,000 - 40,000
Cadmium, Cd	0.05 - 70
Chromium, Cr	1 - 200
Copper, Cu	0.05 - 600
Iron, Fe	1,000 - 50,000
Lead, Pb	1 - 400
Manganese, Mn	24 - 550
Mercury, Hg	0.2 - 2.0
Nickel, Ni	15 - 150
Zinc, Zn	30 - 500
Chlorinated Pesticides	Nil - 10
Polychlorinated Biphenyls, PCB	Nil - 10

Aspects Associated with Disposed Dredged Material

28. The characteristics of disposed dredged material can induce other environmental problems in the area of a disposal site. Impervious material will promote surface water ponding and potential contamination of surface water from runoff. Also, ponded water provides an ideal habitat for water-breeding insects such as mosquitoes, making the disposal site a possible health hazard to surrounding areas. Controls such as surface grading and drainage systems can be designed to prevent ponding.

29. The texture and moisture content of the dredged material will determine the amount of material that can be deposited at a given site. Fine-grained material with a high moisture content will consolidate as pore water is forced out by the weight of overlying material, thus reducing the original volume. However, sandy material will usually maintain the same volume as delivered to the site. The potential for dust will also be determined by texture and moisture properties. Fine-grained materials have more potential for the creation of dust than coarse-grained materials.

30. The type of material can also affect future use of a disposal site. Consolidated fine-grained material is adequate as a base for construction of buildings or industrial sites. Recreational sites can be developed on almost any type of material provided no noxious odors are produced from organic matter decomposition. Analysis of dredged material characteristics prior to deposition is necessary to ensure adequate protection of the environment and to determine future use of the completed site (Krizek et al. 1973).

CHAPTER 2: FACTORS AFFECTING THE ENGINEERING AND TECHNICAL FEASIBILITY OF INLAND DISPOSAL

Site Selection

31. Detailed guides for the selection of dredged material disposal sites are reported in the literature (Baratz 1973; U.S. Army Engineer District, San Francisco, 1974; International Engineering Co., Inc. 1975; International Working Group 1975). Suggested site selection processes vary considerably among sponsoring agencies depending on a number of factors, including:

- Proximity to dredging project.
- Economics.
- Availability of site.
- Environmental acceptability.
- Social and institutional constraints.

32. Essentially all of these guides are useful in locating traditional, marine, marsh, or island disposal areas. As noted, only inland sites located at a distance from the dredging project were considered in this study.

33. Criteria which have been used by decision makers for many years for the land disposal of solid and semisolid wastes can be applied to the technology of dredged material disposal. Detailed discussions of site selection considerations are reported in various EPA-sponsored research (Meyer 1974; U.S. Environmental Protection Agency 1974b, 1975b, and 1976; and Stearns et al. 1976). Information presented below is based largely on a current EPA-sponsored study by SCS Engineers (Stearns et al. 1976). The study encompasses the present state of the art of solid and semisolid waste disposal and presents criteria for the selection of inland waste disposal sites.

Site Selection Problems

34. Proper site selection is basic to dredged material disposal and can be assured only if it occurs through a rational

planning process. Potential problems can arise if dredged material is disposed at a hastily located or improperly situated site. These problems include:

1. Environmental problems - Dredged material deposited on land may cause environmental problems due to various factors, including:
   a. Leachate migration through soil leading to groundwater contamination.
   b. Erosion of dredged material by runoff.
   c. Washout of disposal area due to floods.
   d. Long-term effects on vegetation.
2. Operational problems - Interruptions and improper site operation can result from a lack of adequate planning. Material delivery and spreading operations can be subject to delays due to improper site location, access, and steep grades.
3. Social, institutional, and legal problems - Approvals from local planning and pollution control agencies are required. Adverse public reaction could result in prolonged disputes over the operation. As a general rule, long-term agreements will be required with landowners for long-term use of the site for disposal.

Minimizing Selection Problems

35. To minimize these site selection problems, it is highly desirable to provide local sponsoring agencies with a list of alternative sites. This list should be provided as early in the planning process as possible. Table 2 suggests pertinent items that would be useful in such a list.

36. Recognition of the need for inland disposal sites will provide time for planning to locate and evaluate sites properly and to execute long-term site use agreements or purchase. The various pitfalls associated with dredged material disposal may not be entirely eliminated, but they may be minimized by adequate and timely disposal site planning before the material is received.

Site Selection Procedures

37. The following basic disposal site selection procedures are suggested:

1. Compile a list of several prospective sites.

2. Evaluate suitability of each prospective site.

3. Select best one, two, or several disposal sites.

Table 2

Minimum Information about Dredged Material Disposal Sites for Alternate Site Selection

- Vicinity map showing all candidate disposal sites and major access roads from the dredging project to the sites. The map should also indicate environmentally sensitive areas such as wildlife, historical sites, etc. that should be avoided along transport routes.
- List of local officials (showing phone nos.) with jurisdiction over dredged material disposal and water quality protection.
- List of site owners (phone nos.) and landowners along access routes.
- List of dredging contractors or local government agencies with heavy equipment that may be useful for material disposal and/or emergency disposal site maintenance work.

Location of Candidate Sites

38. An initial survey of all possible dredged material disposal sites in the area should be the first step in site location. This survey can be facilitated by use of both a large-scale base map of the area and U.S. Geological Survey (USGS) topographical maps. The large map should show major roads, schools, military installations, residential neighborhoods, water bodies, parks, and other significant land uses. The local county road department or planning agency could supply such a map. The USGS map is useful to indicate ground

topography and general land use. However, ground truth data should be collected to supplement map data. All alternative sites identified should be marked on both maps to facilitate subsequent evaluation of their acceptability for dredged material disposal.

39. Prospective sites can be identified by various approaches. For example, ownership of land that appears vacant can be determined by study of the maps, reviewing appropriate property records of the local county assessor, and the compiled ground truth data.

40. Alternatively or in combination with a map search, an aerial or ground reconnaissance of the area could indicate potentially suitable sites. Sources could include aerial photography, Earth Resources Technology Satellite (ERTS) mosaics, and false infrared imagery.

41. Another means to determine where suitable sites might be situated is to interview various major landholders or managers in the area such as those listed in Table 3. Consultation with local planning officials can aid in location of prospective sites.

42. Essentially any vacant plot of land should be considered. However, sites of historical significance should be omitted. For a listing of such sites refer to "National Register of Historical Places," Federal Register, February 1974, and also confer with local historical and archeological societies.

43. When canvassing property owners, it should be emphasized that this is a preliminary survey to locate several alternative sites from which the one or two or several best suited will undergo a final selection process.

44. Existing disposal sites should be considered where possible. Such sites may offer additional capacity, room for expansion, or materials could be marketed or used productively to make room for more material.

Evaluate Suitability of Candidate Sites

45. Once the sites are identified, basic background data on each site should be gathered. Use of a comprehensive form, such as presented in the checklist (Part III), can facilitate data gathering and ensure that most pertinent information is obtained. Basic site

Table 3

Sources of Information for Determining Sites Suitable for Dredged Material Disposal

Type of Land	Local Contact
Government Property	
• Federal government	
- Military facilities	Facility/Post/Base or Installation Engineer of appropriate service
+ Military reservations	
+ Communications installations	
+ Weapons/ammunition/equipment depots	
+ Training camps	
- Bureau of Land Management (BLM)	BLM, U.S. Department of Interior
- National Forest land	U.S. Forest Service, U.S. Dept. of Agriculture
• State and Local	
- Excess highway property	Right of Way Office, State and County Highway Depts.
- State Forest land	State Forest Department
- Recreation land	State and local Recreation Departments
- Municipal or industrial waste disposal sites (active or inactive)	Local public works, sanitation, or health department
Private Property	
- Oil company property or leases	Oil company officials, BLM, U.S. Dept. of Interior
- Mining company property	State Department of Natural Resources
- Agricultural land	Grange, local industrial/agricultural realtors
- Industrial waste disposal sites	Industrial waste contractors

(Continued)

Table 3 (Concluded)

Type of Land	Local Contact
Private Property (continued)	
- Utility company property	Local utility officials
- Rock quarries	Local industrial realtors
- Gravel pits	Local industrial realtors

information can be gathered from various sources (Table 4). The specific factors considered are discussed below.

46. In general, it is useful to judge the acceptability of alternative available sites according to several factors. These factors can also be used as guides in selecting alternative sites for consideration. Table 5 summarizes the most important factors to consider when searching for a dredged material disposal site. Other criteria would be developed for each specific dredged material disposal project to reflect local conditions. These factors are defined in terms of criteria that should be met before material is deposited on any site. Table 5 also shows examples of situations where criteria are or are not met. The basic rationale for these criteria are discussed below to further aid in selection of a suitable site.

47. Land use compatibility. Land use compatibility relates to the extent to which development of a dredged material disposal site would conflict with present and future on-site and adjacent property use and value. The site must meet zoning and land use requirements or be situated such that a variance to allow land filling is possible. In any event, it may be necessary to relocate utilities, structures, and other facilities. Sites that otherwise offer ideal conditions for dredged material disposal may not be acceptable if they are in residential, recreational, or certain industrial areas.

48. The major issues usually raised by the public in opposition to dredged material disposal sites focus on potential for property devaluation, loss of receational space, and the impact of the ultimate disposal site use on the local area.

49. Most property devaluation occurs when a site is first proposed. The anticipation of property devaluation that will be caused by the existence of the disposal area may make residents sell quickly and at lower prices. This can alter the property tax rate structure in the area, incrementally increasing the tax rate in other sectors. The preexistence of a disposal site, on the other hand, may not cause property devaluation in relation to the potential development of the area (Harrison and Chisholm 1974).

Table 4

Sources for Basic Information on Prospective Inland Dredged Material Disposal Sites

For Information Concerning:	Contact:
Area base maps	• County road department • City, county, or regional planning department • U.S. Geological Survey (USGS) office or outlets for USGS map sales (such as engineering supply stores and sporting goods stores)
Site maps	• U.S. Department of Agriculture (USDA), Agricultural Stabilization and Conservation Service (ASCS) • Local office of USGS • County Department of Agriculture • Surveyors and aerial photographers in the area • USGS Office, local companies
Geology	• USGS reports • State Geological Survey reports • Professional geologists in the area • Geology Department of local university
Soils	• USDA, Soil Conservation Service (SCS) • USGS reports of area • Geology or Agronomy Department of local university

(Continued)

Table 4 (Concluded)

For Information Concerning:	Contact:
Hydrology	• Private and public suppliers of water • USGS water supply papers • State or regional water quality protection agencies • USDA, SCS • State or Federal water resources agencies • Local health departments
Topography	• USGS topographic maps • USDA, ASCS
Vegetation	• County agricultural department • Department of Agriculture at local university, local arboretum
Land Use	• City, county, or regional planning agency
Meteorology	• U.S. Weather Service • Nearby airports • U.S. Air Force installations • National Climatic Center
Wildlife Use and/or Terrestrial Biology	• State and Federal Fish and Wildlife Departments • National Marine Fisheries Service • Wildlife Departments of local universities

Table 5

Summary of Dredged Material Disposal Site Selection Factors

Factor	Criteria
Land Use	Planned use of the site for dredged material disposal should be compatible with on-site and adjacent land use. Dredged material disposal in a residential neighborhood may not be compatible.
Water Quality/ Hydrology/ Surface Features	The site should not be a source of water pollution. Disposal on porous soil overlying potable groundwater in an area subject to flooding or an area of uncontrolled surface water flow would not meet this criterion. Sites that do not overlie groundwater or where an adequate impermeable layer is present are likely to offer the best protection for groundwater. Control systems for runoff can adequately protect surface water in the vicinity of the site.
Soil Characteristics/ Geological Conditions	Site soil characteristics should prevent leachate migration to groundwater sources. The subsoil of a disposal site located over potable groundwater should be fine-grained, impermeable material, or the site should be lined with similar material to reduce the rate of lateral and downward migration of liquids through the site.
Meteorological Conditions	The site should not be situated in an area of high rainfall and/or extreme wind conditions.

(Continued)

Factor	Criteria
	Moisture addition to deposited material can result in leaching of contaminants to groundwater and runoff to surface water systems. Wind conditions can make the disposal site a nuisance to surrounding areas and can also result in the transfer of contaminants to the area.
Access	Existing access routes into the site should be of all-weather construction. A site that cannot be readily and economically accessed is of little use. Use of temporary surfaces should be considered first.
Terrestrial Biology	The terrestrial biology of the site and adjacent areas must be evaluated to protect any established habitats. An area harboring an endangered species may not be suitable as a disposal site.
Social Factors	Public opinion should be carefully assessed when locating a disposal site near a populated area. Vocal citizen groups can have a decisive impact on site selection.
Institutional Factors	All Federal, State, and local legislation regulating dredged material disposal and land use must be identified for each site. Existing laws may prohibit dredged material disposal at a site that may otherwise be environmentally, socially, and economically compatible.

(Continued)

Table 5 (Concluded)

Factor	Criteria
Economic Factors	Capital and operating costs, environmental protection costs, and transportation costs will affect the selection of a site. Cost comparisons of candidate sites should determine the most feasible.

50. Recreational and industrial land use losses are primarily due to the single land use associated with disposal. However, recreational as well as industrial areas can benefit from dredged material disposal by the filling of marginal lands. Such filling can ultimately result in an increase in the amount of land available for recreational or industrial development.

51. The uncertainty or lack of control by neighborhoods or local communities over ultimate site plans is a source of major opposition on a political level. Site sponsors have varying amounts of control over the ultimate use of a disposal site. During the initial site selection phase, tentative plans for future site use should be discussed with local residents involved (Harrison and Chisholm 1974). Site sponsors should strive to adopt a guaranteed final site use plan to ensure that future problems do not arise and to allay fears of local citizens that the site may remain undeveloped.

52. Dredged material disposal sites located on prime land should not be discounted as long as environmental and public health standards can be met. However, in such cases the plan should provide for eventual productive uses of the area.

53. Water quality. Dredged material is a potential source of water pollutants. However, not all land-deposited dredged material will contaminate an area's water resources. It is important to ensure that dredged material does not become a source of water pollution. Thus, the officials responsible for dredged material disposal must be prudent in site selection.

54. Various physical conditions of a site determine the extent to which water-quality impairment may be possible.

1. Soil characteristics.
2. Subsurface hydrology.
3. Geologic conditions.
4. Surface features (topography, water bodies, and vegetation).
5. Meteorological conditions (precipitation, evaporation, humidity, and wind).

55. Thorough consideration of the important soil and hydrogeologic factors for each candidate disposal site may not always be possible because detailed data on all alternative sites may not be available and accurate investigations can be quite costly. It may often be necessary to initially narrow the selection by consideration of other factors, so that final confirmation of hydrogeologic characteristics by site investigation is necessary for only one or two possible sites (American Society of Civil Engineers 1976). Important factors excluding a site from further consideration might include adamant public opposition or local ordinances prohibiting disposal. Use of the checklist ensures that these factors are properly evaluated.

56. Basic soil and hydrogeologic features should be assessed or estimated when considering any site for dredged material disposal. The interrelationships between a site's soil, geological, topographic, and hydrologic features determine the potential for contamination of local water resources by dredged material constituents. Figure 3 (Phillips, Eng, and Nathwani 1976) illustrates this interaction for a hypothetical disposal site. Although many factors are important, a little basic knowledge of a site's physical conditions can eliminate poorly suited sites.

57. Soil characteristics. Soil characteristics at a disposal site are of primary importance. Available information shows that suitably graded and compacted soils can impede downward migration of leachates; coarse soils will enable flow to occur readily (Phillips, Eng, and Nathwani 1976, and Phillips and Eng 1976).

58. To evaluate drainage characteristics, soil permeability and texture data are necessary. In many areas, such information is available from the USDA, Soil Conservation Service (SCS), or the local State, county, or university extension offices dealing with agricultural matters. The USGS may also have relevant soil data on file.

59. In general, for coarse-grained dredged materials, it is best to locate a disposal site with fine-grained soils of low permeability. These characteristics are common to clays and silts.

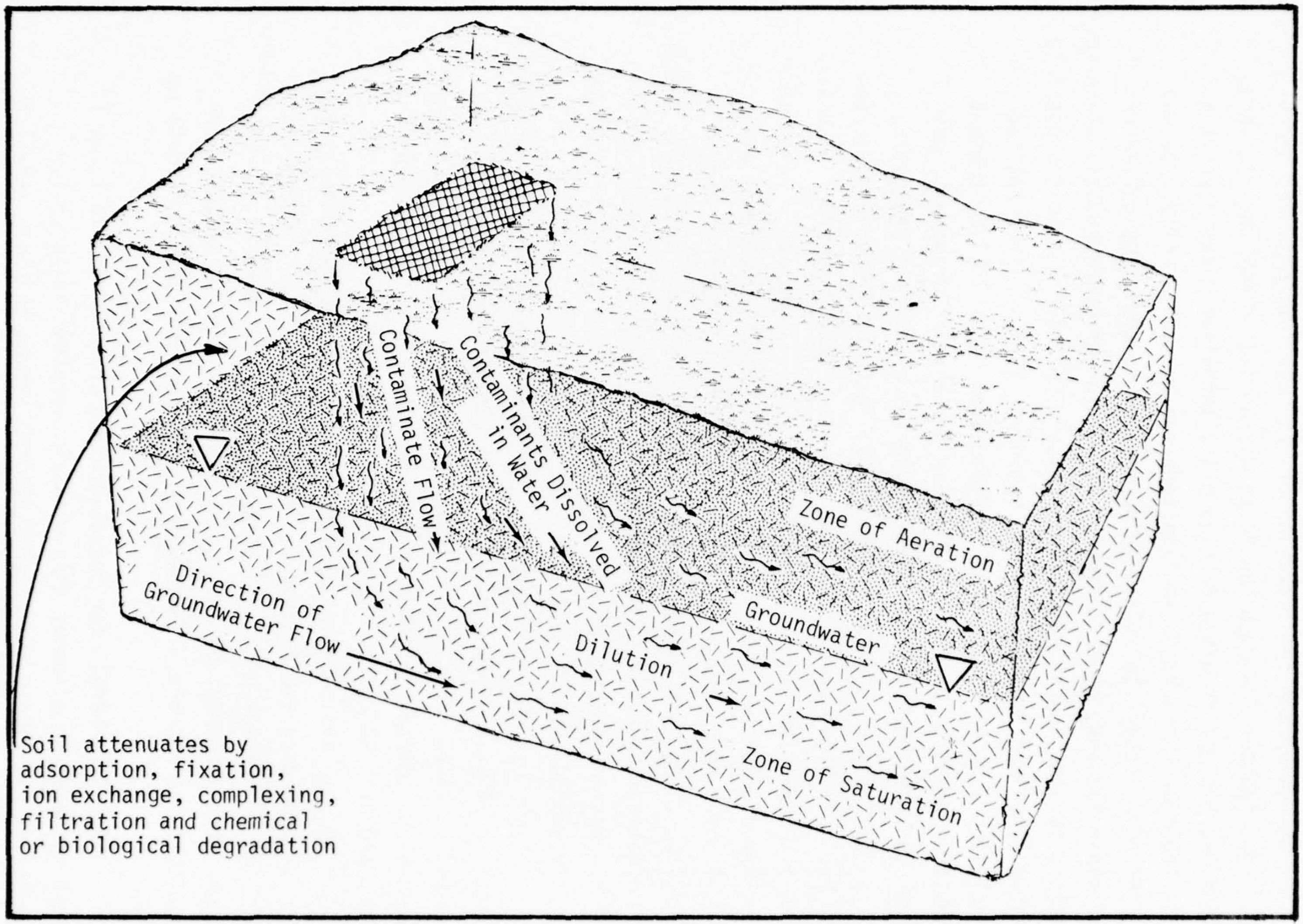


Figure 3. Transport mechanisms of contaminants as they migrate through the soil system (Modification of Phillips, Eng, and Nathwani 1976)

Low permeability reduces the rate at which liquids can move through the soil. In addition, the capacity for the adsorption of contaminants is relatively high in fine-grained soils, because of their great surface area.

60. The thickness of a site's subsoil is also an important consideration in judging the soil's value as a barrier. For example, several hundred feet of relatively permeable coarse-grained sand may provide a barrier as effective as 20 ft of clay. The stratum provides time and surface area for stabilization of any leachate including adsorption of contaminants onto soil particles and filtering of particulates before reaching groundwater (Salvato et al. 1971).

61. Prospective disposal sites that have poorly suited soils should not be hastily dismissed. Clayey and silty dredged material or imported soils can be used effectively to create a barrier or liner (Bartos 1977a). Other liner materials are also available, such as sheet plastic or rubber membranes. The long-term integrity of artificial liners in waste disposal uses, however, has not been demonstrated; thus, caution in their use is warranted (Shimp 1973; Geswein 1975; and Haxo and White 1976).

62. <u>Subsurface hydrology</u>. Hydrology data on groundwater characteristics are also useful in evaluating the potential for contamination at any given site (Hughes, Landon, and Farvolden 1971). The basic hydrologic information needed is:

1. Depth to groundwater.
2. Historical fluctuations in depth to groundwater.
3. Direction of groundwater flow.
4. Groundwater-quality characteristics.

Available information may be sufficient to define these parameters. Groundwater conditions in many areas are well documented, especially if the local water supply is derived totally or in part from aquifers.

63. <u>Determination of groundwater depth</u>. If groundwater conditions at a prospective site have not been mapped, review of logs and pumping records for wells in the vicinity is helpful. All records of water well depths in the area should be reviewed and documented. Only

those wells within a radius of about 0.5 mi of the prospective site should be investigated since the possibilities of aquifer continuity decrease with distance.

64. Further information concerning groundwater can be derived from a general knowledge of the site's location. Generally, the water table lies deeper in arid regions (<5 in. of rainfall) than in humid regions. The depth to the water table tends to change with surface topography: it is deeper beneath interstream areas and shallower in lowlands, and it coincides with the surface of perennial streams. The water table is usually closer to the soil surface in relatively impermeable materials such as clays than in relatively permeable materials such as coarse sands. In dense unfractured rock, the water table may be absent or discontinuous (LeGrand 1964).

65. Groundwater depth fluctuations. It is important to determine if significant fluctuations in groundwater elevation occur. In some areas, natural or artificial groundwater recharge may raise the water level into areas considered from a cursory investigation to be safe for disposal. Thus, the data of water supply agencies as well as historical records of groundwater fluctuations must be studied. Well owners and operators can also provide information on historic fluctuations in groundwater level.

66. Determination of groundwater flow direction. Knowledge of the direction of groundwater flow is essential. A disposal site upstream from a water supply well would be less favorable than a site downstream, all other factors being equal. Also, the location of site-monitoring wells must be based on accurate groundwater flow direction data.

67. If local water supply and other agencies' records are insufficient to determine flow direction at a prospective site, several rules of thumb may be used in place of these data. Groundwater moves in accordance with the hydraulic gradient, from points of high elevation to points of lower elevation. On a map showing the site and surrounding area, all existing wells should be located. The depth to groundwater in each well should be noted and the elevation of the

groundwater surface with respect to sea level should be calculated. Approximate contour lines that connect wells of equal groundwater elevation can be drawn on the map. The direction of groundwater movement will be perpendicular to these contour lines.

68. Where local well data are unavailable, it may be necessary to conduct a limited drilling program to determine groundwater depth data. Test wells can also help define subsurface soil and geological conditions. Figure 4 illustrates how groundwater flow direction can be determined with three test wells. Ideally, the wells should be situated so that the site is encompassed within the triangle formed by the wells. By using this simple method of determining the depth to groundwater, an approximate determination of flow direction can be made. Knowing the elevation of three points on the groundwater surface plane (a plane determined by the three well water surfaces), the direction of the plane's dip can be calculated and illustrated, as shown in Figure 4.

69. Exploratory wells at an alternative disposal site should be cased with polyvinyl chloride (PVC) pipe for later use in site monitoring. Samples of soil should be retained for analysis.

70. Groundwater quality. It is generally preferable to locate a disposal site over brackish or otherwise unusable groundwater than over a potable water source. Thus, basic information should be gathered concerning the water quality of underlying aquifers. These data establish baseline quality conditions and will be useful for determining postdisposal water-quality impacts if the site is used for disposal.

71. Local health departments and water companies generally have water-quality records for aquifers used for drinking water supply. These records should provide a sufficient basis for a comparison of the relative merits of those alternative sites overlying such aquifers. Records could also provide baseline quality data for the selected site.

72. Depending on how extensive and current the existing records are, it may be desirable to analyze samples of the groundwater for selected constituents after designating the disposal site. Water-

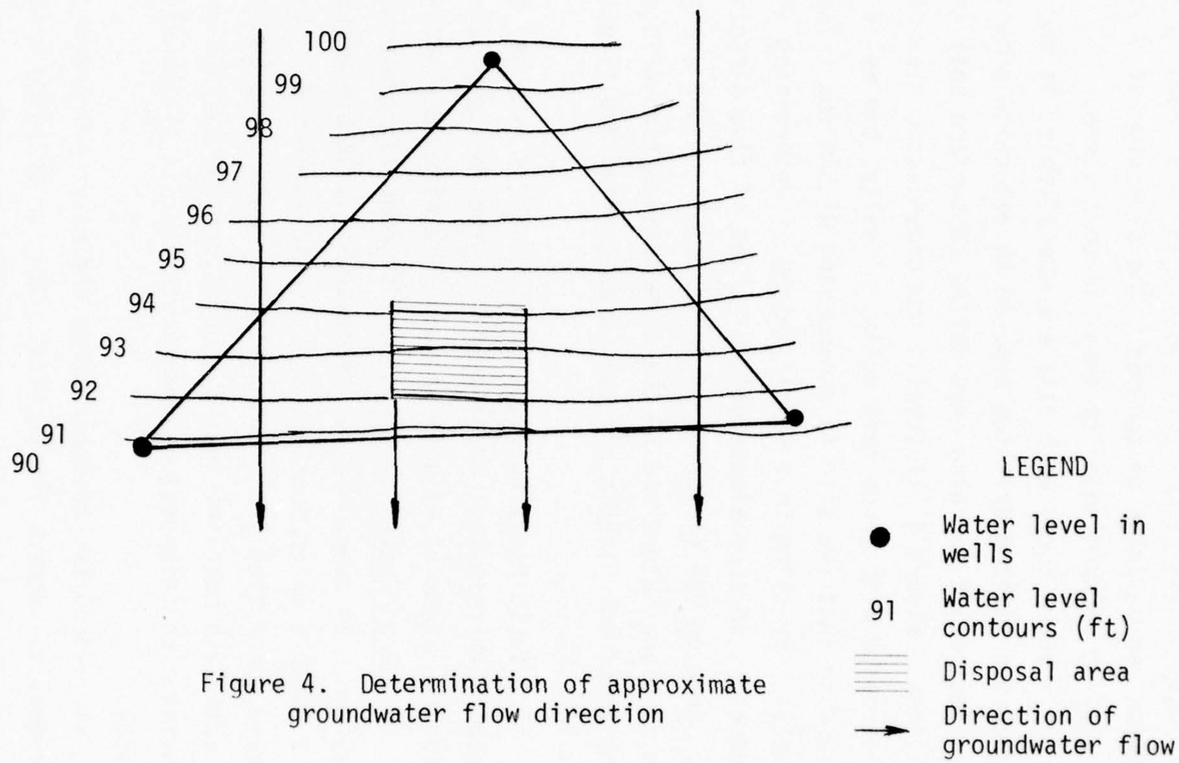


Figure 4. Determination of approximate groundwater flow direction

quality parameters of interest include pH, heavy metals, PCB's, pesticides, total phosphorus, total and inorganic nitrogen, and oil and grease. Only those parameters missing from the records or those which have not been analyzed for a considerable time need to be determined.

73. Geological conditions. Geological conditions of interest in evaluating alternative disposal sites include landslide or slump potential, faults, and seismic activity.

74. Observations of site topography and information on soil types can aid in evaluating the potential for sliding or land slumping at a site. A slide hazard would be expected if the site rests on a slope of more than 2:1 or is adjacent to the toe of such a slope. Investigation by a qualified engineering geologist or soils engineer would be useful in determining the slope stability if a site with such features were desirable for other reasons.

75. The location of all known faults and slide zones on or near the site and the historical record of activity on these faults and zones should be investigated. Such information can be obtained from the USGS or local geology consulting firms familiar with the area. If geological evidence indicates that movement has occurred recently or is a threat, the site may be unsuitable for dredged material disposal. A major seismic event could affect the site by inducing liquefaction causing loss of strength in the fill material or berms. Seismic activity could also damage access roads, runoff diversion facilities, and structures at the site, resulting in considerable economic loss.

76. Surface features. Surface topography, water bodies, and vegetation at and near a prospective disposal site can influence the potential for surface and groundwater contamination and damage to vegetation from dredged material disposal.

77. In evaluating the suitability of alternative sites, it is useful to determine what relative topographical positions they occupy. Seven different topographical positions or landforms are defined as

upland flat, upland valley side, upland crest, upland ravine, valley side, valley terrace, and floodplain.

78. Figure 5 (Sendlein and Palmquist 1975) illustrates the relative location of each type of landform. The general characteristics of these landforms from Sendlein and Palmquist (1975) and their suitability for dredged material disposal are discussed below. The suggested order of preference for dredged material disposal site location in an idealized situation in which only a minimal amount of water passes through the site is:

- First preference: Upland crest, upland ravine, upland valley side, and upland flat
- Second preference: Floodplain, valley terrace, and valley side

79. Upland sites are preferred to valley sites because of the greater likelihood of the site remaining dry. However, the greatest potential for extensive groundwater contamination exists for upland sites which are in groundwater recharge areas; and the least potential for extensive groundwater contamination exists for properly placed valley sites which are in groundwater discharge areas. In the case of dewatered dredged material disposal, the possibility for groundwater pollution is not as likely as the possibility for surface water pollution; hence upland sites are preferred. If the dredged material contains no deleterious constituents, disposal in a floodplain may be acceptable; however, local regulations may prohibit operation of a disposal site in the floodplain. In all cases, it is expected that the disposal area will be protected from washout due to surface runoff either naturally or by design features.

a. First preference. Upland crest, upland ravine, upland valley side, and upland flat positions are generally preferable locations for dredged material disposal sites because groundwater flow is usually away from them, and surface water occurrence is limited to directly incident precipitation and off-site runoff. The ravine and valley side positions require surface water diversion to reduce the amount of water entering the site. Except in very impermeable materials or during extremely wet seasons, groundwater levels in these positions should lie well beneath the disposal area.

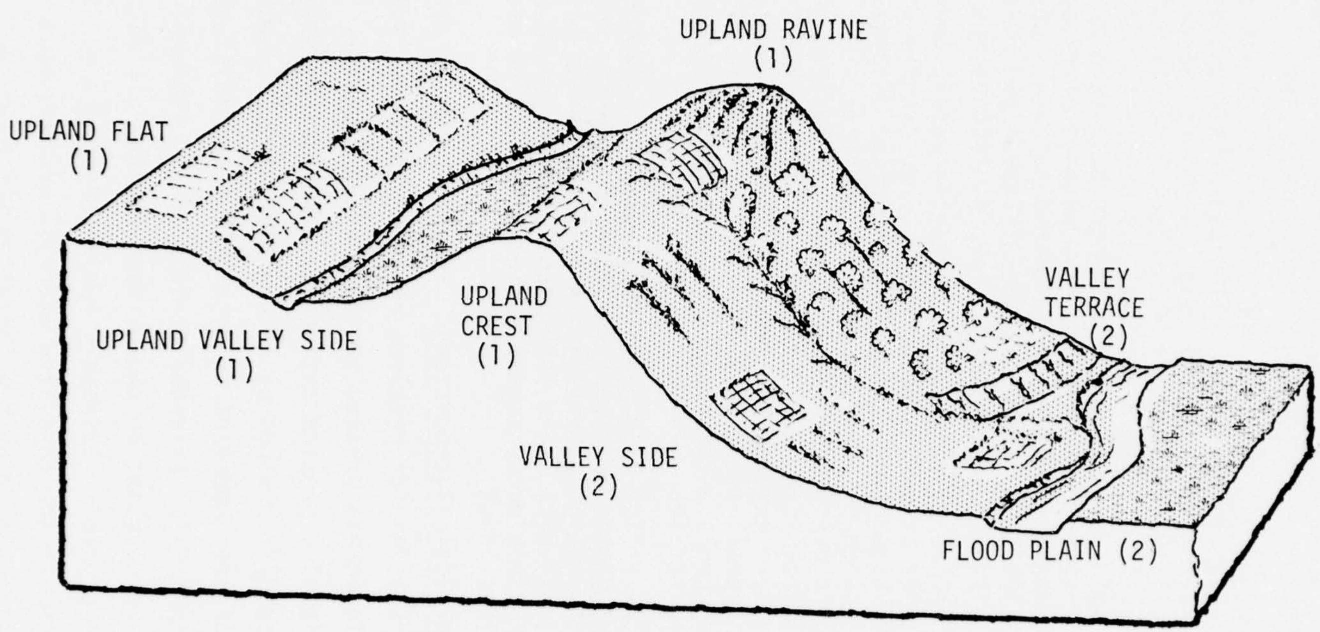


Figure 5. Relative location of various landforms (Modification of Sendlein and Palmquist 1975)

One drawback to disposal site location in these landforms is that they are often in groundwater recharge areas. As for every alternative site, the possibility of groundwater contamination should be investigated in terms of the soils and hydrology of the site.

b. Second preference. The suitability of the floodplain, valley terrace, and valley side positions depends upon the potential for flooding, depth to groundwater, and soil characteristics. In general, it is inadvisable to locate a dredged material disposal site within the limits of a floodplain. There have been many instances of water contamination from washout of disposal sites because the sites were located in areas subject to flooding. Even provision of levees and dikes is no lasting solution since dike maintenance may be neglected.

Permeable soils usually underlie valley terraces, sometimes at very shallow depths. No surface water should be present at or near a prospective disposal site located on a valley terrace landform. The likelihood of groundwater intersecting a valley terrace site increases as the site position approaches either the valley wall or the level of the modern floodplain. Also, disposal sites should not be situated in gullies or dry channels without provision of proper runoff diversion facilities.

The valley side position is either a regional or local discharge or recharge site with moderate to deep contamination potential. A valley side can also be subject to washout. The likelihood of both groundwater and surface water contamination results from disposal at this level.

80. Meteorological conditions. Prevailing winds are an important consideration for problems relating to odors, dust, and the transfer of contaminants present in the dredged material. Proper site selection can minimize problem incidence. Wherever possible, sites should be sheltered from winds by natural features. Evaporation and humidity rates can be important in controlling the moisture content of the dredged material. Extended periods of dry temperatures can create desiccation cracking on the surface of the fill and subsequent ponding of surface water. Extremely humid conditions can result in excessive moisture in the deposited material and subsequent leachate formation. The importance of precipitation was discussed in a previous paragraph.

81. Site access. Proposed methods of transporting dredged material to an inland site include rail haul, truck haul, barge movement, and conveyor belt systems. These transportation systems require land access routes. Site access routes that pass through or near residential areas, hospitals, and business areas may be undesirable because of noise or traffic hazards. The importance of noise pollution potential, as well as increased traffic, distinguishes site access as a major site selection criterion. To accommodate loaded truck traffic, road grades along access routes and within the disposal area itself should not exceed 7 percent. Bearing capacity of all roads must be sufficient to accommodate the largest fully loaded trucks expected to serve the site. The roads must be wide enough to allow two-way truck traffic, or a feasible one-way traffic pattern must be established.

82. Importing foreign contaminants to an area. Before establishing an inland disposal site, Federal and State departments of agriculture and the Code of Federal Regulations, Title 7, Chapter III, Part 301, "Domestic Quarantine Notices," should be consulted for regulations regarding transport of dredged material.

83. Terrestrial biology. The terrestrial biology of the inland area must be carefully evaluated for short- and long-term effects of dredged material disposal. Important biological species of plants and animals, especially rare, threatened, or endangered species, must be identified and precautions for their protection implemented if any such species exist in the area. The 1973 Endangered Species Act (PL 93-205) gives protection to endangered and threatened species and to their habitat. Included within this legislation is a list of plant and animal species that qualify for protection. Several states have instituted similar laws (U.S. Department of the Interior 1974 and Hunt 1976).

84. Social factors. Public attitudes regarding the location of a disposal site near a specific community must be carefully gauged. In addition to an assessment of public opinion, the decision-makers must recognize that small but vocal special-interest groups can have a decisive impact on the acceptability of any site. These entities (e.g.,

business interests, local residents, recreation groups, conservationists) must be identified and their probable reactions to a specific site anticipated. Strong feelings against the construction of a disposal site could eliminate that site from consideration (Baratz 1973). A further discussion of public opinion is presented in Chapter 7.

85. Institutional factors. Site selection procedures must include the consideration of all legal and institutional issues bearing on dredged material disposal in general and at the particular site(s) being studied. Baratz (1973) suggested compilation of Federal, State, and local laws relevant to the disposal of dredged material and pertinent to the site in question. The judgment of knowledgeable persons concerning the flexibility of some legal constraints should be solicited. A further discussion of legal factors is presented in Chapter 8.

86. Economic factors. Costs associated with a dredged material disposal site are dependent upon prevailing land and equipment costs, method of land acquisition, labor rates and other operating costs, the existence of access routes to the site, and environmental protection costs. Preliminary cost estimates for candidate sites should help establish the economic feasibility of securing the site for dredged material disposal. Further discussion of economic factors is presented in Chapter 5.

Final Site Selection

87. The alternative sites best conforming to the previously discussed factors and criteria should be selected for use. This selection process is facilitated by use of the checklist which is designed to evaluate those factors and criteria. Sites with major problems that cannot be satisfactorily mitigated by design should be dismissed from further consideration.

Arrangement with Site Owners

88. Once an environmentally acceptable dredged material disposal site has been selected, it is necessary to negotiate a purchase,

lease, or easement agreement for its use with the owner or manager. Site acquisition was described by Murphy and Zeigler (1974). Several factors should be included in the site use agreement and resolved during negotiations:

1. Duration of easement if property not purchased.
2. Procedures for site access easements.
3. Notification of intention to use the site for disposal purposes.
4. Responsibility for disposal permit fees, etc.
5. Responsibility for site operation, cleanup, and maintenance.
6. Carefully detailed termination clauses.
7. Responsibilities for postdisposal monitoring.

Site Preparation

89. A site to be used for dredged material disposal usually requires some preparation prior to initial deposition of the material. The extent of preparation necessary is dependent on conditions at the site. Suggested site preparation procedures are reported in U.S. Army Engineer District, Chicago (1977b).

Access Road Construction

90. An access road from the nearest road serving the site should be constructed to a convenient entry point into the disposal area. A suitable access road into a disposal site should meet the following basic conditions (Stearns et al. 1976):

1. Width: Approximately 10 to 20 ft depending on the volume of material requiring disposal and the types of delivery equipment used.
2. Grade: Less than 7 percent, especially if delivery trucks will be going upgrade while loaded.
3. Bearing capacity: Sufficient to carry tandem axle trucks with a gross vehicle weight of about 70,000 lb over extended periods of time. May need to be much greater if special offroad type earth haulers are used.

Grading and Removal of Rocks, Vegetation, and Topsoil

91. All boulders, logs, rocks, and other hard materials and all brush should be removed from the intended disposal area if a liner is to be installed. The site should be graded to about 1 to 2 percent and smoothed to the extent possible. Grasses and low shrubs need not be removed unless they pose a threat to the integrity of the liner. Depending on the final use of the completed site, topsoil can be removed and stockpiled for use as final cover.

Surface Drainage Diversion

92. Drainage control should be a part of site planning. Drainage patterns at the site and adjacent areas should be studied to determine surface runoff into the fill area. Natural drainage channels emptying onto the planned disposal area should be diverted so that the potential for runoff entering the fill is minimized. Drainage channels can be earth ditches if low flows are expected. Lining with asphalt or Gunite may be necessary to handle higher flows. Half-round corrugated metal pipe can also be used for drainage channels.

Dike Design and Construction

93. It is unlikely that dredged material would contain much excess liquid after being dewatered and transported to the disposal site. However, as a precaution, it may be necessary to design and construct dikes around the site to prevent any excess water from overflowing from the disposal area. Dikes should be seeded with native vegetation to control erosion. Provision of a basin on the downstream side to contain liquid runoff would also be desirable. The DMRP has sponsored work on dike design and construction under Task 2C, "Land Improvement Concepts."

Subsoil Preparation

94. In some cases, it may be desirable to prepare the subsoil at a site that would not otherwise be acceptable for dredged material disposal. Preparation might include lining the bottom and sides of an above-grade site with a fine-grained dredged material or soil imported from off-site (Bartos 1977b). This material would act to retard or eliminate migration of leachate from the material placed within the area.

95. Table 6 (Stearns et al. 1976) summarizes available information concerning membrane-type liners that may be applicable to disposal areas. Such liners might be used instead of soils to retard leachate migration. However, synthetic membrane materials do not yet have a proven record of long-term service.

96. The need for a liner at a site will be determined not only by the nature of the dredged material, but also by the hydrogeologic conditions at the disposal site. When evaluating suitable liner materials, the selective placement of indigenous fine-grained soils or fine-grained dredged material should be considered.

97. Use of membrane liners generally requires subgrading and removal of angular objects that might puncture the liner material. If the dredged material contains sharp objects, placement of a protective soil cover over the liner is required. Methods of installing the various liner materials vary depending on the type of liner and local conditions. Liners are generally shipped in large rolls and are placed in position in the field. Joints can be sealed by suitable adhesives or, in some cases, by heat treatment. Manufacturer's specifications usually require certain liner section overlapping, installation temperatures, and other procedures specific to membrane liner materials.

98. Research and development in liner technology, including the integrity and longevity of membrane liners, is in its early stages. New liner materials are currently under development, and further research results are expected. Consequently, it is best to consult manufacturers' representatives for up-to-date information on the availability and applicability of membrane liners for disposal areas.

99. In certain hydrogeologic conditions, groundwater levels must be controlled by ditching or pumping to prevent failure of the liner due to hydraulic pressures from below (U.S. Environmental Protection Agency 1974a). A model groundwater pumping system for a dredged material disposal site is reported by the U.S. Army Engineer District, Chicago (1977a and 1977b).

Table 6

Summary of Data on Membrane Liners Potentially Usable for Dredged Material Disposal Areas

(Stearns et al. 1976)

Membrane Type/ Material	Thickness Avail. mils	Placement*	Expected Longevity	Est. Installed Cost Range+ $ per sq yd
Polychloroprene (reinforced with polyester)	32	Exposable to sun	>1 yr	6.75 - 8.55
Thermoplastic polyester	7	Exposable	<1 yr	Experimental
Polyvinyl chloride (PVC)	10-30	Unexposable	<1 yr	1.17 - 2.16
Coal tar pitch and PVC	100	Unexposable	<1 yr	1.50 - 3.50
PVC reinforced with nylon	10-30	Unexposable	<1 yr	1.50 - 3.50
Chlorosulfonated polyethylene	20-45	Exposable	<1 mo	2.88 - 3.37
Polyethylene	10-20	Unexposable	<1 mo	0.90 - 1.56

* All liners require subgrade preparation by removal of sharp objects and rocks and may require a coarse soil base. Unexposable liners must be covered with soil to prevent damage by ultraviolet sunlight and atmospheric contaminants.

\+ Cost of subgrade and soil cover not included. These costs can range from $0.10 to $0.50 per sq yd per ft of depth.

CHAPTER 3: DREDGED MATERIAL TRANSPORTATION AND METHODS OF DEPOSITION AT DISPOSAL SITE

100. Transportation systems for the inland disposal of dredged material are being evaluated by General Research Corp. (GRC) (Souder et al. 1976). The following section summarizes basic information presented in the GRC study. For detailed analyses of each system, the original report should be consulted.

101. Depending on the economics of the situation four modes of transportation could be suited for transportation of dewatered dredged material to inland disposal sites. The systems include rail haul, barge movement, truck haul, and belt conveyor movement. This study did not consider slurry pipeline systems.

Rail Haul

102. In a rail haul system, the unit train concept is suitable for material transportation if the volume of material to be moved at any one time is large enough to fill a complete train (i.e., 5,000 to 10,000 tons), and regularly scheduled transport of dredged material inland can be expected. The minimum movement required to support a unit train operation is about 500,000 cu yd per year spread over all or most of the year from Point A to Point B, where Point A represents an existing disposal or dredging area and Point B would represent an inland disposal area. Conceptually the distance from Point A to B could range from 5 to 1500 mi.

103. Efficient loading and unloading procedures are mandatory for a cost-effective rail haul system. Loading procedures could include heavy equipment (backhoe digger, front-end loader, bucket wheel excavator) for loading the material onto a portable belt conveyor. The conveyor in turn could feed a fixed conveyor to a stockpile area. Material in the stockpile area could be bottom fed to an underground high-capacity belt conveyor which loads a feedout bin. The loading procedure would be such that the train would maintain a slow continuous movement under the feedout bin which loads each car as it passes.

Unloading procedures would require an excavated disposal area or elevated train tracks to bottom dump the material from the rail cars. Rotary dump systems in which two or more cars can be tipped at one time are also available. The rotary system is much more expensive but provides adequate discharge of materials with a high moisture content.

104. Additional considerations associated with rail haul of dredged material include:

1. The material being moved must be dry enough to free-fall out of bottom dump rail cars or out of feeder bins.
2. Unit train lengths can sometimes be restricted where local laws place limits on the maximum amount of time that a road intersection can be blocked due to train traffic.
3. Regulations established by recent environmental legislation must be met. These would include the Clean Air Act of 1970, concerning the prevention and control of air pollution, and the Noise Control Act of 1972, concerning noise emission standards. To prevent dry, fine-grained dredged material from blowing off of hopper cars, the cars may have to be covered.
4. A unit train system with dual use would require washing of the cars after unloading the dredged material to avoid the possible contamination of other material types being transported to another area. An additional problem with this plan would be that of residue disposal after car washing.
5. Weather conditions could adversely affect the transportation of dredged material by rail haul. Excessive rainfall or freezing temperatures could significantly affect the handling characteristics of the material unless the cars were covered.

Barge Movement

105. Barge movement is an efficient, economical means of transporting bulk materials. A barging unit for transporting dredged material inland would include one tugboat (about 1,000 hp) and steel bottom-dump scows (approximately 15,000 cu yd capacity each). To determine the number of barging units required for a given application, the annual volume to be transported, estimated loading and unloading time, barge speed, and the distance over which the material is to be moved must be analyzed.

106. Barge-loading operations would usually require truck haul of excavated dredged material from the rehandling areas to the barge mooring dock. It may be desirable to evaluate the feasibility of using a conveyor belt system rather than truck haul for this transport function.

107. The unloading cycle would be facilitated by clamshell-type cranes which move the material directly from the barge into trucks. The number of unloading cranes should be determined from annual quantities of material. Loaded trucks haul the dredged material from the unloading dock to the disposal area.

108. The effect of barge traffic on recreational activities, especially water sports such as boating and fishing, should also be considered. Polluted dredged material could leak or spill into waterways from barging operations and at the loading and unloading facilities causing local pollution of the waterway.

109. As in the case of rail and truck haul in open-topped cars and trucks, both freezing temperatures and excessive precipitation could influence the material handling characteristics of the dredged material being transported.

110. A "user charge" could be enacted by the Congress as a means to finance continued maintenance and/or improvements to the inland waterway system. Such a charge would increase the cost of dredged material barge transport, thereby decreasing the attractiveness of this mode.

Truck Haul

111. Truck haul for short distances could be an economical choice for the transport of dredged material. Truck haul has the particular advantage of geographic flexibility which often limits consideration of other transportation modes. In general, truck haul does not require elaborate and expensive loading and unloading facilities. A major limitation of truck movement of dredged material is size and weight regulations of trucks for open road usage. A net weight limit of 50,000 lb is followed by most trucking companies.

112. Since the weight of the dredged material is relatively high (density approximately 100 lb/cu ft), the truck size limitation is not significant in comparison to the weight limitation. For the transportation of large volumes of dredged material for distances up to 150 mi, open-topped, 25-ton dump trucks are recommended. Tank-type trucks are also available, but open-top trucks facilitate loading and unloading operations.

113. A typical loading facility for the truck haul operation is based on the loading facility for the rail haul system (Paragraph 103). The unloading procedure at the distant disposal areas should require no special facilities and would involve back dumping the material within the disposal area.

114. Considerations associated with truck movement of dredged material include:

1. Air pollution controls on vehicle exhaust emissions under the Clean Air Act of 1970.
2. Vehicle noise emission standards under the Noise Control Act of 1972.
3. Local ordinances restricting operating hours during the day and roads to be used.
4. Noise and traffic restrictions in areas such as hospital zones and residential neighborhoods.
5. Potential problems with spills requiring extensive cleanup (in the case of an accident).
6. Weather conditions such as snow and ice creating hazardous driving conditions.

Belt Conveyor

115. Use of belt conveyor systems as primary transportation modes is suitable for the movement of bulk materials for distances up to 60 mi. The basic advantages of belt conveyor transportation are low operating cost, high volume movements possible, minimal noise and air pollution impact, no disruption of highway traffic, and no dependence on waterways and/or rail lines being in place. Limitations of the system include high initial investment cost potential, unavailability of right-of-way, and possible vandalism.

116. The loading facility for the conveyor system would be patterned after the rail haul loading facility. The unloading facility at the distant disposal area could involve the use of a moveable radial belt track to feed large stockpiles for subsequent dispersal in the disposal area.

117. The following factors associated with belt transportation of dredged material should be considered:

1. Since belt conveyor systems are comprised of segments, if one segment fails to operate, all other segments must be stopped to avoid pile-up of material and equipment damage. Accidents may result in extensive damage unless automatic controls to stop the conveyors are provided.

2. Weather conditions can affect surface conveyor systems. For example, failure in the mechanical system can result due to rust.

CHAPTER 4: DISPOSAL OPERATIONS

Receipt of Material from Delivery System

118. Transfer of dredged material from the delivery system to the disposal area will depend on the transportation system and the disposal site characteristics (see transportation section, Chapter 3). For truck transport and barge movement systems, the material would likely be deposited into the disposal area with no special handling. Delivery system characteristics, however, may require that the materials be mechanically removed from the delivery equipment to a stockpile area and then conveyed to the final disposal location.

Stockpile Area

119. The stockpile area should be located as near as practical to the disposal area and be readily accessible to the disposal equipment. If the dredged material contains excessive moisture and is porous, and if the site foundation soil is permeable, it may be advisable to line the stockpile area with clay or other impervious soil or with an impervious membrane. The liner will contain or impede the outward flow of liquid into the ground. Soil liners may not be well suited for a stockpile area that is intended for reuse since equipment operating in the stockpile area may inadvertently remove the liner soil along with the dredged material.

Spreading and Compaction of Material

120. Dewatered dredged material can be spread and compacted in the disposal area with most track or wheel dozers or loaders. The total thickness of material to be placed will depend on the quantity of material to be disposed, the size of the area, compaction characteristics, and local topographic limitations.

121. The final surface of the disposal area should be maintained at no less than 2 percent to promote runoff (American Society of Civil

Engineers 1976). Excessive surface grades, however, should be avoided to minimize runoff velocity and erosion.

Final Cover

122. A completed site should be covered with a final layer of material that is resistant to erosion and surface cracking and provides an adequate base for vegetative covering. The final cover can be original topsoil that has been stockpiled, on-site soils, dredged material, or imported material.

Equipment

123. The number and type of equipment units required depends on the volume of dredged material to be disposed each day and on the size of the site. Dredged material spreading can be performed using almost any available heavy earthmoving equipment unit such as track or wheel dozer, track or wheel loader, or track-type tractor. Equipment size and weight and required engine horsepower are dependent on the material characteristics, site terrain, and underlying conditions. Equipment specifications (Caterpillar Tractor Co. 1976) should be consulted for site-specific equipment.

124. Track dozers equipped with a bucket would be appropriate for constructing containment berms that may be required. Track or wheel dozers would usually be adequate for placing the material in the disposal area. The same equipment can be used to apply final cover if necessary and to grade the filled site surface.

Personnel

125. The number and capabilities of personnel required will vary according to the quantity of dredged material and its rate of delivery to the site. At least one equipment operator for each shift is necessary for each piece of heavy equipment used. Other personnel may

be useful to spot material delivery at the proper dumping location and to direct traffic. It is usually advisable to assign a minimum of two persons to the disposal site at any time so that one can aid the other in case of accident.

126. In general, certain duties must be performed at any disposal operation, whether by an individual or by a team assigned to a specific task. Necessary personnel categories and their basic tasks include:

Title	Function
Site Coordinator	Oversees all on-site activities
Unloading Personnel	Assist in unloading dredged material from delivery system
Heavy Equipment Operators	Move material from the unloading area, place it in the disposal area, compact the deposited material, and grade the surface after site completion

Energy Considerations

127. Operation of an inland dredged material disposal site will consume gas, oil, and electric energy. Energy use should be established as a significant parameter in the equipment and transportation mode selection processes.

128. The most significant amount of energy consumption will be during transportation of the material to the site. Proper care and maintenance of vehicles and delivery systems will help minimize energy use. On-site energy use will be diesel fuel consumption for heavy equipment operation. All equipment should be maintained on-site and kept in top working order to maximize efficiency and minimize fuel consumption.

CHAPTER 5: ECONOMIC FACTORS AFFECTING THE FEASIBILITY OF INLAND DISPOSAL

129. An important factor in the development and operation of a dredged material disposal site is cost. Total costs include the following items:

1. Disposal site capital costs.
2. Disposal site operating costs.
3. Environmental protection costs.
4. Transportation costs.

130. The total cost of each dredged material disposal site is highly dependent on site-specific conditions such as material volumes, need for access road construction, types of equipment used, site topography, prevailing labor wage rates, and dredged material transportation method. Land costs can vary significantly with geographic region and even within the same area.

131. Unit costs for various aspects of disposal operations and environmental controls are shown in Table 7 (Stearns et al. 1976). These data are useful in estimating disposal costs for a given volume of dredged material.

Disposal Site Capital Costs

132. All equipment, land, access roads, and facilities that must be purchased or constructed to initiate and continue disposal operations are included in this category. Drainage facilities and utility relocations are part of the capital cost requirements.

Disposal Site Operating Costs

133. Annual recurring costs for such items as equipment operation and maintenance, and wages and benefits for all site personnel are included.

Environmental Protection Costs

134. Costs include all control facilities such as ground and surface water monitoring systems, leachate collection and treatment

Table 7

Estimated Unit Costs for Dredged Material Disposal Operations

(Stearns et al. 1976)

	Item	Unit Cost* ($/unit)
1.	Access road construction** (if needed)	4.00 to 4.50 per ft
2.	Site preparation (clearing, scarifying, grading, where necessary)	600 to 700 per acre
3.	Drainage channels+	0.50 per ft
4.	Monitoring well installation#	180 to 250 or more per well
5.	Seeding surface of disposal area with grass	180 per acre
6.	Site geophysical and engineering studies	10 to 12 percent of site development costs

* All costs in 1976 dollars.
** 20 ft wide gravel road.
\+ Earth trench.
\# Depends on many variables, including soil type, depth to groundwater (if any), and drill rig used.

systems, dust and noise control devices, and operation and maintenance of all environmental protection and monitoring facilities. These costs may be incurred even long after the site is completed.

Transportation Costs

135. The cost to transport dredged material to each site must receive special attention. The cost of transportation to the disposal site can account for a major share of the total amount spent for dredged material disposal.

136. The following discussion of transportation options and costs is derived from data provided by GRC (Souder et al. 1976) for the transportation of dewatered (dry) dredged material.

Rail Transportation Costs

137. Rail costs can be divided into three basic categories: loading, transportation, and unloading. Unit costs decrease with increasing distance travelled and with increasing annual volumes of material transported. For larger volumes the primary cost element is the rail transport cost, which is effectively constant for volumes in excess of 500,000 cu yd per year. For short distances and/or low volumes, the composite costs rise substantially because the costs associated with the loading and unloading facilities dominate the transportation cost.

Barge Movement Costs

138. Barging costs depend on the volume, distance, and route to be travelled. Combined loading and unloading costs are constant for a specified volume movement regardless of the distance the barging unit travels. However, a cost can be allocated to loading and unloading rates which drop significantly as distance increases, reflecting the spread of fixed handling costs over longer distances.

139. For a given distance, the unit transportation costs will be constant regardless of annual volumes being transported; however, unit costs for a given annual volume decrease somewhat with increasing

distance travelled. For all volumes, loading and unloading costs dominate the combined costs for short distance movements. As this distance increases, transportation cost dominates. For long distance movements, where the transportation cost is dominant and constant for various volumes, the total combined unit cost also becomes relatively constant for varying annual volumes.

Truck Haul Costs

140. Transportation rates for various volumes are constant at given distances, while material handling costs drop sharply. Cost data for truck haul are based on the following three assumptions: (1) estimated average unit costs are used; these vary with geographical locations and the trucking company selected; (2) rates for short distance movements vary widely; and (3) strong competition exists within the trucking industry. Consequently, these rates cannot be directly applied since a negotiated rate is usually arranged with a given carrier.

Belt Conveyor Movement Costs

141. The cost to move dredged material by belt conveyor is based on the following three assumptions: (1) right-of-way is available at no cost; (2) the route will not traverse unusual terrain; and (3) the projected economic life of the belt conveyor system is 20 years.

142. For low annual volume levels and short distance movement, both handling and transportation costs are relatively high and contribute nearly equally to the total cost. At longer distances, the transportation costs become the dominant factor. It is necessary to consider large annual volume movements of bulk material before belt conveyor systems become economical in comparison to the other transportation modes.

Life Cycle Costing

143. Life cycle cost analysis involves the consideration of all costs associated with the procurement and operation of a dredged material inland disposal site throughout its service life. Included are the procurement of the site and all capital equipment, dredged

material transport, operation and maintenance, and all other economic factors associated with a particular disposal operation. A life cycle cost analysis is a step-by-step procedure which leads to the identification of the economically optimum option when several options are available.

System Options

144. The first step in this analysis is to prepare a set of system options. All components and aspects of the disposal operation, including land, equipment, facilities, material transport, operation and maintenance, site resale, etc., must be considered in determining the available system options. The total set of system options would cover all feasible combinations of the various components.

Equipment Costs and Life Span

145. After completion of the set, the next step is to identify the cost of each component and the expected life span of the site and all capital equipment. Cost estimates are required for all capital purchases, including future equipment replacement, operation and maintenance, equipment salvage values, and the resale value of the site upon completion. In some cases there is a direct relationship between life span and costs. For example, the frequency of routine equipment maintenance affects maintenance cost and equipment life span. Delaying routine maintenance to save money can shorten equipment life.

Trade-Off Analysis

146. To make trade-off analyses of system options that have different cost flows over time, a method of making all costs comparable is required. Introduction of discounting makes this comparison possible. In most cases the discount rate represents the opportunity cost of capital to the user. Inflation rates also should be specified. There should be different inflation rates for each cost sector, including rates for utilities, maintenance and repair, labor, capital equipment, land values, etc. It is possible, as a simplifying assumption, to assume that all inflation rates and the discount rate are equal.

Cost for Each System Option

147. The final step in the life cycle cost analysis is to calculate the total life cycle cost for each system option in the set. In a simplistic form, the life cycle costing in mathematical terms can be represented by:

$$C_{T_i} = \left[C_1 + t(C_2+C_3)+C_4-C_5-C_6\right]_i$$

where C_{T_i} = total life cycle cost for system i

C_1 = initial capital costs

C_2 = annual operating and maintenance costs, discounted after the first year

C_3 = annual transportation costs, discounted after the first year

C_4 = discounted value of replacement equipment with inflated purchase price

C_5 = discounted equipment salvage values

C_6 = discounted site resale value

t = site life span

The system with the lowest value of C_T would be the optimum system, considering economics alone, of all options evaluated in the set.

CHAPTER 6: ENVIRONMENTAL FACTORS AFFECTING THE FEASIBILITY OF INLAND DISPOSAL

148. The transportation and disposal of polluted dredged material can adversely affect the environment along the transportation route, at the site itself, and in adjacent areas. Therefore, controls must be implemented to mitigate any environmental pollution. The following sections discuss potential environmental problems associated with the disposal of polluted dredged material and possible controls available.

Potential Impacts from Material Transport

149. The various methods of transporting dredged material to an inland site can have the following impacts on the environment:

1. Blowing dust from open trucks, rail cars, barges, or conveyor systems can result in particulate release to the air and possible health hazards.
2. Odors present in the material may be released to the surrounding area. If the area is inhabited, citizen opposition to the disposal site may result.
3. Exhaust emissions from the transport systems can increase the concentration of hydrocarbons and other potentially harmful constituents in the air. Exhaust from transport systems must meet air quality emission standards.
4. Noise levels can be increased due to transportation system traffic or operation of mechanical hardware.
5. Increased traffic congestion could contribute to a greater accident hazard. Congestion and hazards could be minimized by site access controls or channelization. Site access routes should be adequately posted; traffic signals may be needed at key traffic points, depending on the number of trucks delivering dredged material to the site.
6. Trucks carrying wet dredged material may leak, causing muddy roads which can cause accidents, blight the surrounding area, and later be a source of blowing dust. For transporting wet dredged material, watertight trucks should be specified.
7. Accidental spills from the various transport systems could affect the health and safety of surrounding

populations and cause potential surface and groundwater pollution, depending upon the nature of the material and location of the spill.

Potential Impacts from Disposal Operations

Leachate

150. The DMRP is currently conducting research on leachate production potential from dredged material disposal sites.* Preliminary results from a laboratory column study indicate that levels of contaminants present in leachate may not be significant. The type of contaminants and range of concentrations expected in dredged material leachate cannot be stated with certainty since this research is still in progress. Leachate characteristics are dependent on characteristics of the dredged material. Table 1 showed these characteristics to be highly variable, with the concentration range for some constituents varying by four orders of magnitude. Much information is known about leachate from sanitary landfills, but municipal refuse and industrial wastes disposed in sanitary landfills have characteristics so different from dredged material that no useful comparison is possible.

151. The mechanics of leachate production and migration at a dredged material disposal site are expected to be similar to those of a sanitary landfill. Research on leachate in sanitary landfills is the subject of many completed and ongoing projects sponsored by EPA and others (Remson et al. 1968; Qasim and Burchinal 1970; Fungaroli 1971; Fungaroli and Steiner 1971; Fenn and Hanley 1973; U.S. Environmental Protection Agency 1974a; Chian and De Walle 1975; Fenn, Hanley, and DeGeare 1975; Phillips, Eng, and Nathwani 1976; SCS Engineers Jan 1976 and May 1976). Discussion of leachate formation and migration is

---

* These investigations are under DMRP Work Units 2D02, "A Study of Leachate from Dredged Material in Upland Disposal Sites and/or in Productive Uses " (SCS Engineers, Long Beach, CA) and 2D05, "Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas" (Univ. of Southern California, Los Angeles).

contained in the section, "Correcting Environmental Problems during Disposal Operations" (Paragraphs 182-189).

Effects of Weather

152. Climatic conditions can influence water quality conditions in the area of a dredged material disposal site. Precipitation may cause erosion, runoff, and infiltration if surface cracks exist. Suspended solids, materials, and dissolved contaminants in polluted dredged material may move with the waterfront and provide a potential source of pollution to surface waters and groundwater.

153. Meteorological conditions can also adversely affect a dredged material disposal site and surrounding area. Wind conditions may cause loose, fine-grained dredged material to become airborne dust, creating a potential health hazard and a source of complaints from local citizens. Wind may also spread whatever odors emanate from the dredged material to outlying areas. Prolonged exposure of the deposited dredged material to warm temperatures can create desiccation cracking on the surface of the fill. Ponding of surface waters in the cracks will result in potential breeding habitats for insects, especially mosquitoes (Mann et al. 1975). Cracked surface areas are also unsightly and can be visually unattractive. Continued maintenance of the surface to fill in cracks can alleviate many of the problems associated with climatic conditions.

Vectors

154. Ponded water in a disposal area supports insect (especially mosquito) breeding. Shallow pools and water-filled cracks are suited to mosquito larval breeding (Harrison and Chisholm 1974; Berlin 1976). Mosquitoes, flies, rodents, and other vectors are a public nuisance and can create a health hazard by transferring contaminants from the disposal site to the external environment (Lee et al. 1976). Also, vector populations present the possibility of spreading diseases to the surrounding area and to site personnel. Proper drainage and maintenance of the fill surface can eliminate ponded water, thereby controlling or eliminating vector populations.

Odors

155. Odors associated with dredged material are found to decrease in intensity rapidly after disposal (Harrison and Chisholm 1974 and Harrison et al. 1976). Dewatered dredged material would present little or no odor problem unless the material is saturated with water and has a high organic content. The organics could undergo anaerobic decomposition and produce malodors. Soil cover material can be placed over the odorous material to minimize odor emissions.

156. Leachate, if present on the surface of the disposal area either through seeps or from a collection system, can also be a source of odor. Chemicals can be used to mask the odors until they diminish with time or until sufficiently dispersed (American Society of Civil Engineers 1976).

157. Other odor sources may emit malodors that people mistakenly assign to the disposal of dredged material. It may be useful to survey the area around a disposal site for alternate odor sources. Gas leaks may be one type of source to consider (Harrison et al. 1976). Odor sources not associated with the disposal site should be identified and publicized so the public is aware that dredged material is not the source.

Noise

158. Noise problems have often been associated with land disposal activities. Heavy equipment operating at the site and delivery vehicle or transportation system traffic contribute to noise impacts. Generally, the noise is similar to that generated by any heavy construction activity and can be a nuisance and a potential health hazard to the surrounding community. Research by EPA (Office of Noise Abatement and Control 1974 and 1975) stipulates noise levels requisite to protect public health and welfare. Current standards should be consulted for disposal site operations.

159. To minimize noise impacts, delivery access should be restricted to established industrial-commercial routes wherever possible. If the disposal site is near residential areas, the operation of heavy equipment should be limited to reasonable hours, and the

engines should be muffled. The use of earth berms and trees as noise barriers may have limited effectiveness in controlling noise. However, if noise control is a problem, a site should be selected at a suitable distance from any inhabited areas and/or be well masked by terrain. On the site, noise control for employees will be governed by existing Occupational Safety and Health Act Standards.

Visual Impact and Aesthetics

160. To make a dredged material disposal site acceptable, every attempt should be made to keep the site compatible with its surroundings. As a general rule, more complaints are registered against operations that are in view of the public than those screened from view.

161. During site preparation, it is important to leave as many trees as possible to form a visual barrier. If necessary new trees and shrubs can be planted. Earth berms can be similarly used. Separation of the site from inhabited areas or roads can be an effective means of minimizing visual impacts. Local topography, fences, or landscaping may sufficiently mask the site (American Society of Civil Engineers 1976).

162. Proper site maintenance can present a good image to the public, thereby aiding in the public's acceptance of the operation. Dead vegetation should be cleared from the site, and the surface should be properly maintained at all times. Landscaping can improve the appearance of a completed disposal site. Principles and practices of landscaping as they relate to the development of dredged material disposal sites are reported by Mann et al. (1975).

Air Pollution and Dust

163. Disposal site equipment will be a source of air contaminants. Proper equipment emission controls should minimize any air pollution from vehicle exhausts. Blowing dust at a disposal site can also add to local air pollution downwind of the site. Severe dust generation can result from excessively dry surface material, from travel over access roads, and from equipment moving dredged material within the site. To minimize dust problems, roads should be all-weather or treated with dust control agents. A cover soil not susceptible to wind erosion

may be necessary. Finished areas should be landscaped as soon as possible. Site operations should be curtailed during excessively windy conditions (Harrison and Chisholm 1974; American Society of Civil Engineers 1976).

Importing Foreign Contaminants to an Area

164. Establishing an inland disposal site at some distance from the dredging project may result in the introduction of foreign plant and animal species and other contaminants. The USDA Cooperative Domestic Quarantine restricts the transport of certain insect vectors and plants. Dredged material transported long distances and across state lines may be regulated under the USDA quarantine. Both State or Federal departments of agriculture and the Code of Federal Regulations, Title 7, Chapter III, Part 301, "Domestic Quarantine Notices," should be consulted for regulations regarding transport of dredged material before and during operation of an inland disposal site. Methods to detect and control the introduction of any suspected foreign insects, plants, viruses, or other contaminants must be implemented.

Security/Safety

165. Any disposal area may appear an attractive playground to children or others. Thus, the site should be surrounded by a natural barrier or fence to discourage entry of unauthorized persons.

Monitoring the Site for Environmental Protection

166. A dredged material disposal site may present environmental problems as long as pathways for contaminant migration from the disposal area to off-site locations are present. Pathways for migration of dredged material constituents can be inherent at the site or may develop after completion of disposal activities due to natural causes or man-induced alterations to the disposal site and/or its environs.

167. Depending on whether the site is owned or leased and on conditions included in a lease agreement, it will be the responsibility of the agency coordinating the disposal operation, the landowner, other agencies, or a combination of these groups to ensure that any

environmental problems will be detected early enough to enable implementation of proper countermeasures. This section presents basic considerations for disposal site monitoring required to detect development of environmental problems.

168. Any activity involving the disposal of polluted material on land will present potential environmental problems. Possible short- and long-term pollution problems must be defined a priori so that a comprehensive monitoring plan may be formulated.

169. Possible environmental problems to be anticipated at dredged material disposal sites include the following:

1. Contamination of groundwater with constituents of the material by:
   a. Leaching of constituents from the dredged material to the groundwater.
   b. Infiltration of groundwater into the disposal area.
2. Surface runoff.
3. Surface settlement and subsequent ponding of surface water.
4. Air pollution from dust generation.
5. Vector breeding.
6. Odors.

Development of a Monitoring Program

170. The form and extent of environmental monitoring to be implemented at a dredged material disposal site depends on the type of dredged material disposal operation, and site hydrogeologic and meteorologic conditions. Also, the monitoring plan must meet requirements of all local regulatory agencies having jurisdiction over various aspects of environmental protection such as water quality, solid waste management, air pollution, and noise. Methods and sampling techniques from Stearns et al. (1976) for monitoring ground and surface waters and soils are discussed below. A detailed sampling program is also presented in Mooij and Eng (1976) and Lehr et al. (1976).

Groundwater Monitoring

171. Basic hydrogeologic features at the disposal site should be known from information gathered during the site selection process. In general, a groundwater monitoring program will entail placement of wells in the groundwater both upstream and downstream from the disposal site. Thus, at a minimum, knowledge of the following data is necessary for monitoring well design:

1. Depth to groundwater and expected fluctuations.
2. Direction of groundwater flow.
3. Quality of groundwater in area before dredged material disposal.

172. When all available hydrogeologic data have been evaluated and monitoring needs established, details of the program design can be specified. A groundwater monitoring system should detect as early as possible any contaminants that may be entering the aquifer and define the contaminated zones. This can be accomplished by a system of wells both upstream and downstream from the site. Depth, placement, and number of wells will be determined by site-specific subsurface characteristics and monitoring objectives.

173. The first wells can be placed downstream from the disposal area. Initially, two or three wells may be aligned perpendicular to the anticipated direction of contaminant movement from the disposal area. The wells should be situated as close as practical to the limits of the material deposit to ensure that any contamination that may occur is detected quickly. If one or more of these downstream wells detect any pollution, assessment of the degree of contamination in each well will aid in defining the limits of the contaminated zone. At least one upstream well should be drilled for determining background groundwater quality.

174. Wells should be constructed of PVC plastic pipe to minimize contamination of sampled water from pipe materials. Any diameter pipe will suffice as long as available sampling devices can fit down the pipe. All wells should be capped.

175. The depth of each monitoring well will be determined by site hydrologic characteristics. Vertical fluctuation of groundwater

levels must be defined so that each well can be installed to extend into the aquifer throughout the year even in dry years. It is good practice to extend the well screen 5 to 10 ft below the lowest expected level of the aquifer and several feet above the highest estimated level, as shown on Sketch B on Figure 6 (Stearns et al. 1976). Figure 6 also illustrates problems that may be encountered if monitoring wells are not suitably screened.

Surface Water Monitoring

176. Any body of surface water within 1,000 ft downstream from a dredged material disposal site should be periodically monitored to ensure water-quality protection. Water sampling stations should be placed at the most likely points of contamination. Surface water samples should be taken as near to the disposal site as possible so that contamination can be detected before spreading to a larger body of water and thereby becoming diluted.

Monitoring Deposited Dredged Material

177. In addition to monitoring a dredged material disposal site for groundwater and surface water pollution, it may be desirable to take core samples of the deposited material at different depths and analyze for contaminants, permeability, and moisture content. The analyses will show the chemical and physical variability of the material horizontally and vertically within the site.*

Soil Analysis

178. Core samples of the soil underlying the deposited material should be analyzed periodically for contaminants contained in the material. The migration patterns of the contaminants and the ability of the underlying soil to attenuate migration can thus be determined (Mooij and Eng 1976).

Laboratory Analyses to be Performed

179. The main purpose of monitoring a disposal site is to determine to what extent contaminants are leaving the site. Table 8 lists those basic parameters that should be analyzed. This list

---

* This variability is being investigated under DMRP Work Unit 2D02 (SCS Engineers, Long Beach, CA).

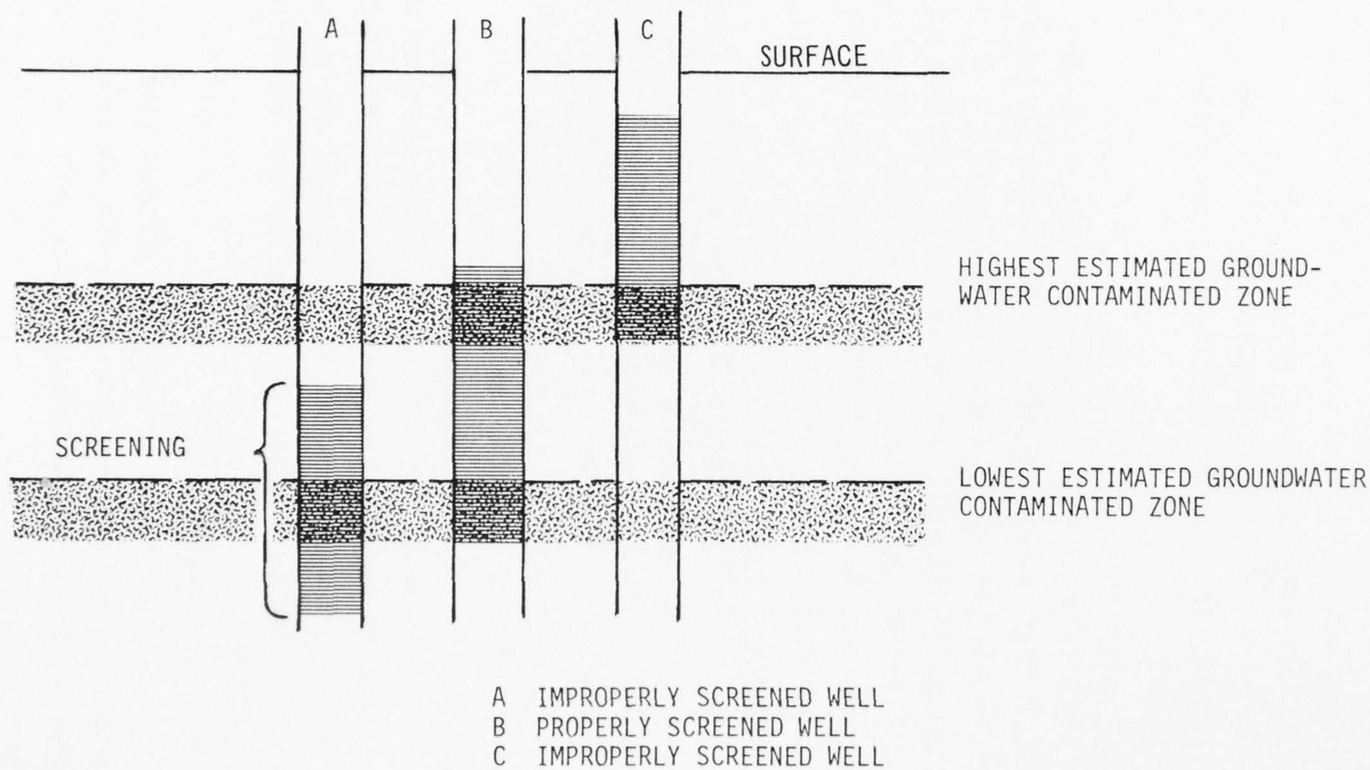


Figure 6. Well screening
(Stearns et al. 1976)

provides a set of parameters for a routine monitoring program aimed at assessing whether or not dredged material is causing environmental problems. A complete analysis of subsoil and water samples should be performed initially to establish baseline conditions. A similar analysis of the dredged material should be conducted to determine which contaminants are present.

Table 8

Water, Dredged Material, and Soil Parameters for Investigation of a Dredged Material Disposal Site

Parameters (All Samples):

- Pesticides
- Heavy metals
- PCB and other toxic chemicals
- Total and Ortho-phosphate
- Nitrogen species
- Oil and grease
- pH
- Eh

Parameters (Dredged Material Samples Only):

- Moisture content
- Permeability
- Grain-size distribution

Monitoring Meteorological Conditions

180. The moisture content of a deposited dredged material depends upon many meteorological factors: the frequency, duration, and intensity of precipitation; air temperature; wind; relative humidity; and the amount of evapotranspiration. Various instruments are available to monitor these weather conditions. A weather monitoring system at a disposal site may consist of a rain gauge, hygrometer, thermometer, and evaporation pan (Garbe et al. 1974). Local data are also available from U.S. Weather Service Stations. It is important that weather data information be recorded continuously and consistently. Air temperature,

relative humidity, precipitation, and evaporation are interrelated. Daily monitoring of data from each instrument provides a method of determining the effect of climate upon a dredged material disposal site.

Correcting Environmental Problems During Disposal Operations

181. A properly designed environmental monitoring system as previously discussed will enable the source and extent of any contamination to be readily detected. Should contamination occur, measures to correct the problem should be taken as soon as possible by the parties responsible. Corrective actions should have two goals: (1) to remedy the cause of the pollution problem and (2) to remove any damage that has already occurred. It is helpful to briefly discuss possible alternative solutions to various pollution problems. Potential problems that may be encountered at a polluted dredged material disposal site, together with suggested solutions, are summarized on Table 9 (Stearns et al. 1976).

Groundwater Contamination

182. Once contamination of the groundwater has been detected, it is necessary to determine both the pollutant source and the extent of the affected area. Groundwater quality and use should be considered to assess the consequences of contamination. Accurate information is essential to guarantee selection of appropriate and effective corrective measures. Once this information is assembled, alternative solutions can be made.

183. Groundwater pollution from a dredged material disposal site can occur as a result of several events acting together or separately:

1. Leaching contaminants by drainage of the liquids contained in the dredged material itself.
2. Flushing of the dredged material by groundwater rising into the mass then seeping out.
3. Leaching contaminants by infiltration of water through cracks in the site surface.

184. Leaching of dredged material. Groundwater contamination may be caused by leachate generated by the moisture present in the polluted dredged material. A gravel interceptor layer lining the site

Table 9

Correcting Environmental Problems

(Stearns et al. 1976)

Problem	Possible Solutions
1. Infiltration of groundwater into dredged material	a. Pump out groundwater to drain upstream area
	b. Construct diversion channels
	c. Construct peripheral subsurface drains to intercept groundwater flow
2. Surface runoff of materials from site	a. Install impoundment dikes or berms
	b. Improve upstream diversion channels
	c. Recycle runoff to disposal area
3. Ponding of water on surface of disposal area	a. Regrade surface, possibly apply more cover soil
	b. Establish vegetation to increase evapotranspiration
4. Leaching of water through dredged material to groundwater	a. Intercept leachate with trench; collect and treat or recycle leachate
	b. Pump out contaminated zone in downstream groundwater
5. Odors emanating from site	a. Cover site with low permeability soil or a membrane liner
	b. Mask odors with chemical additives

(continued)

Table 9 (Concluded)

Problem	Possible Solutions
	c. Control seeping leachate if it is source of odor
6. Vector breeding	a. Control ponding water and surface cracks
	b. Add cover soil if dredged material is source of nutrients
7. Noise	a. Restrict construction activities to certain hours
	b. Route transportation of material away from inhabited areas
	c. Locate disposal site away from inhabited areas
8. Dust	a. Plant vegetation around periphery
	b. Wet down access roads
	c. Discontinue operation during windy conditions

If above-noted remedial actions do not solve environmental problems, investigate further to be certain that the disposal site is actually the source of detected contamination. If it is, removal of material to another site may be last resort to positively curtail pollution threat.

(Figure 7) and a collection sump constructed at the most likely point of discharge (Figure 8) can intercept leachate before it penetrates the aquifer.

185. When and wherever groundwater contamination occurs, appropriate remedial actions will necessarily be site-specific. If all other methods have failed, contaminated groundwaters can be pumped from the water table. This procedure will require fairly accurate knowledge of the boundaries and degree of contamination of the leachate affected zone for proper well placement. Where a shallow aquifer exists, an interceptor trench may provide an adequate solution. Judicious disposal site selection, design, and operation could preclude groundwater contamination problems that require costly pumping solutions.

186. Infiltration of groundwater into deposited dredged material. Contamination can result from the infiltration of groundwater into the fill caused by local mounding or areal changes in the groundwater level. Three techniques are available to divert groundwater from the fill. Pumping of this water at a short distance upgradient may lower the groundwater to a level no longer in contact with the dredged material. Diversion channels may also provide a solution; such channels, lined with corrugated pipe, gravels, or screened PVC pipe, would transport water away from the fill, thereby preventing contamination. Peripheral subsurface drains to intercept groundwater flow offer a third alternative.

187. If, after implementing the remedial actions noted above, the monitoring system still indicates that groundwater pollution continues, more radical actions may be necessary. Excavation and removal of all dredged material from the offending site would be necessary only in the most extreme instances of groundwater contamination. Such measures would be most likely where inadequate site selection investigations failed to indicate the possible pathways for contamination. The excavated material could either be relocated or temporarily stockpiled until a low permeability soil or membrane liner can be installed in the disposal area.

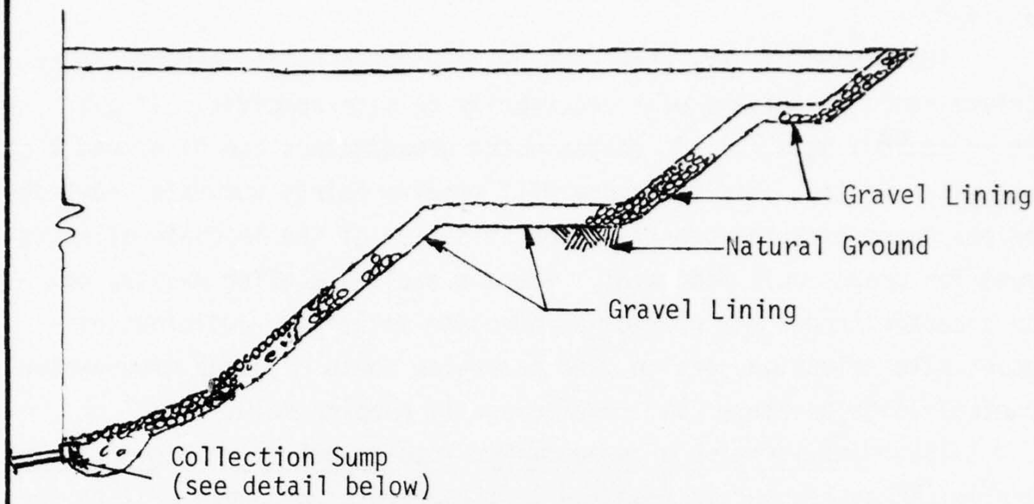


Figure 7. Leachate gravel interceptor lining

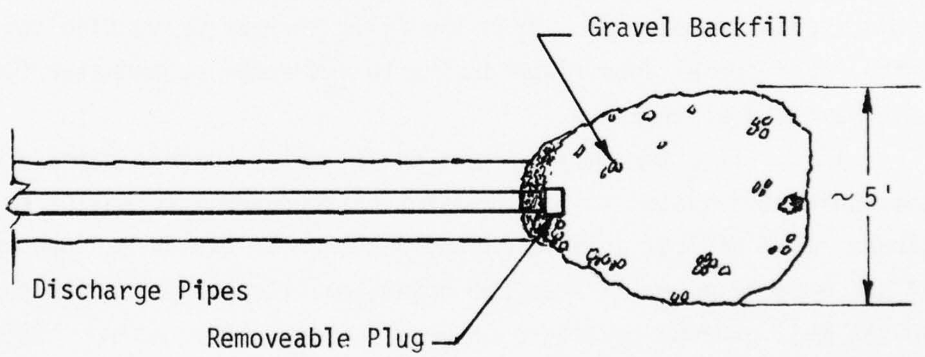


Figure 8. Leachate collection sump

188. Vertical infiltration. Vertical infiltration of water through surface cracks in the fill may leach contaminants from polluted dredged material into the groundwater. The rate of infiltration or water intake is greatly influenced by the water content and surface conditions.

189. In the event of surface failure, it will be necessary to discern why such a failure occurred. Continued maintenance of the site surface may be necessary to prevent cracking. Use of a different type of cover soil may be required to prevent future cracking and erosion.

Surface Water Contamination

190. Surface runoff from dredged materials in a disposal site presents another potential environmental hazard. Runoff can be impeded by the construction of dikes or berms to contain the runoff within the site boundaries. Runoff could be recycled through the material if the groundwater is protected and if net rainy season evapotranspiration or evaporation exceeds precipitation.

191. On-site surface waters should be controlled in a dredged material disposal operation to reduce ponding. Maintenance of upstream diversion trenches will reduce the flow of water into the area. Sedimentation basins should be provided to prevent discharge of runoff with excessive suspended soil particles. However, runoff should not erode the topsoil if the surface slope is gentle and planted with grasses.

192. Corrective measures for controlling vectors, odors, noise, aesthetics, air pollution, and dust were discussed in a previous section, "Potential Impacts from Disposal Operations" (Paragraphs 154 through 163).

Summary

193. The characteristics of any contamination problem at a dredged material disposal site will be site-specific; appropriate remedies will have to be tailored to fit distinctive local features. As a last resort, the removal of dredged material to another site may be required. Removal and redeposition of the material at another site

would be very costly, and it should be confirmed through an extensive monitoring program, that the disposal site is actually the source of contamination before undertaking relocation of dredged material. If material redeposition proves necessary, it is vital to ensure that the new disposal site be prepared in such a way that environmental degradation is not repeated.

194. The disposal of dredged material is a necessary part of all dredging projects. Until more detailed and in-depth operational knowledge of polluted dredged material inland disposal becomes available, use of the procedures presented here can aid in implementing proper disposal operations to ensure environmental protection.

Correcting Environmental Problems after Disposal Operations

Site Cleanup

195. After deposition of dredged material, all signs of disposal activities should be removed from the surface adjoining the disposal area and surrounding areas. Any areas used for stockpiling should be returned to their predisposal appearances. A final cover over the completed site may be required if underlying material is permeable or if odor problems persist. This cover may consist of on-site soils, suitable dredged material, or material imported from off-site. Low permeability soils are preferable since they impede water infiltration. The surface should be compacted and graded to a slope of not less than 2 percent to ensure adequate runoff. Slopes greater than about 4 percent may tend to cause surface erosion. Access roads may be left in place to facilitate future use of the site for recreation or other purposes. Cleanup operations for a dredged material disposal site are reported in U.S. Army Engineer District, Chicago (1977b).

Revegetation

196. Grasses should be planted over the site surface to prevent erosion and improve site aesthetics. Grasses selected for cover plantation should germinate rapidly, constitute a perennial stand, and provide thick coverage. Native grass or other vegetation may establish

itself naturally over the deposited material due to the available water and possible plant nutrients. Seeding of preferred grass species may be necessary, however (U.S. Army Engineer District, Chicago 1977b).

197. While agricultural crops may be grown on some dredged material, the health effects of human or animal consumption of the resulting food products are not well defined. The effects will depend on many factors including crop type and dredged material characteristics. Until further information is available, it is safest to advise that no crops intended for human or animal consumption be planted within the disposal area, especially if the dredged material contains significant concentrations of heavy metals and carcinogenic compounds (Lee et al. 1976).

CHAPTER 7: SOCIAL FACTORS AFFECTING THE FEASIBILITY OF INLAND DISPOSAL

Public Attitude

198. The public will generally resist plans to locate any type of land disposal facility near their homes. Site sponsors must be cognizant of the public's negative attitudes toward land disposal facilities, recognize the need to play an active role in gaining public acceptance, and realize that a defensive attitude should be avoided. Research projects on public opinion and its role in public projects are currently being conducted by EPA, the National Science Foundation (NSF), and other agencies (U.S. Environmental Protection Agency 1972a; Clark and Goddard 1973; Lackey 1973; and Hudson 1974).

199. The major obstacles to public acceptance of land disposal sites are not usually technical; they relate to people and politics. Baratz (1973) outlines the area of public involvement in civil works projects. The Corps of Engineers has issued a number of publications concerning public education and involvement as well as guidelines for environmental assessment (Department of the Army 1967, Sept. 1970, Nov. 1970, Apr. 1971, May 1971, and 1975). The EPA has also issued documents outlining representative public participation efforts (U.S. Environmental Protection Agency 1972b and 1975b).

200. Introduction of true public input can be a costly and time-consuming effort. Manpower requirements, printing and circulation of documents, and public communication (newspapers, radio, etc.) can be expensive. Costs to procure and activate a disposal site can increase appreciably due to inflation if public hearings delay project initiation. Several actions can be taken to win public support, including the enlistment of professional assistance. The following activities are recommended by the American Society of Civil Engineers (1976) and the U.S. Environmental Protection Agency (1975b) as a means of securing public acceptance:

1. Present a positive public image of the project.

2. Establish a public information program by:

   a. Making site plans available to the public for review and input.

   b. Keeping local landowners and residents informed through letters and special meetings.

   c. Enlisting the support of special-interest groups and having them participate in the public information program.

   d. Keeping local officials informed on the project and enlisting their continuing support.

   e. Setting up a citizens' advisory committee and including it in the decision-making process.

   f. Disseminating general information on the project through the mass media.

   g. Publicizing notice of hearings to ensure that all interested and affected parties are notified.

Present a Public Image

201. An inland disposal site for polluted as well as non-polluted dredged material can be an environmentally sound disposal operation if run properly. This fact should be stressed. Dredged material disposal sites would be screened from public view, landscaped, and well operated. Ultimate plans for final site use should be determined early in the project and prominently publicized. It should be stressed to the public that significant efforts are planned to minimize any adverse effects on local residents.

202. A gauge of citizens' attitudes can be very helpful in pinpointing issues of public concern. Knowledge of potential areas of and reasons for opposition, determined through a public attitude survey, can aid the sponsor in developing a dredged material disposal site which will meet with public approval. Since an attitude survey can also indicate reasons for potential public support, it can provide the sponsor and local officials with positive goals to guide in disposal site planning.

203. Surveys intended to assess public attitudes should follow certain specifications if accurate results are to be obtained. The survey questions should be designed to tap public opinion on potential problems of the study area. Personal interviews should be conducted

with adult members of randomly selected households. A statistically significant number of respondents should be included in the sample. Since the development and pretesting of the questionnaire will take 5 or 6 weeks and data collection and analysis will take up to 8 weeks, at least 3 months should be allowed for the administration of an opinion survey. It is often desirable to retain specialists to design questionnaires, conduct the survey, and compile and analyze results. The sponsor should weigh the results carefully, both in developing the disposal site and in presenting the plan to the public.

Establish a Public Information Program

204. All aspects of the site development plan, including engineers' recommendations, should be made available for public review and evaluation. Re-evaluation and modification of the plans may be necessary before the site is accepted. A long-range plan should be included with the implementation schedule.

205. Establishment of an extensive public information program at the earliest possible time is prudent. Public involvement to the maximum extent should be sought with feedback to planners and decision makers.

206. Local residents and landowners. Local residents and landowners who may be affected and even displaced by the project and those who are to be its neighbors must be kept informed of current planning. Special information dissemination programs through letters, special meetings, and other means are often necessary to minimize opposition and to preclude legal conflicts that may result from unwarranted assumptions and fears.

207. Special-interest groups. A wide variety of special-interest groups (including sportsmen's clubs, conservation groups, and taxpayer organizations) may be concerned with the project and its effects. Areas of concern will be widely varied, but every effort should be made to anticipate them and to address them at the earliest possible stage.

Many well-informed special-interest groups can be expected to add their support to the intended project and may be valuable in helping to continue the public information program.

208. Approaches to public presentation. In many cases, public opposition to proposed land disposal operations can be related to lack of knowledge or understanding of the fundamentals involved. Consequently, a well-planned information and education program is highly desirable, and in many cases, required. Effective presentation will usually entail a combination of some or all of the following approaches.

209. Local officials. Close liaison should be maintained with all local officials who may be directly or indirectly concerned with the project or its effects. The maximum amount of useful information should be passed on to these officials at the earliest possible time to ensure their thorough understanding and continuing support. Properly informed officials may in turn become useful and integral members of the public information program through public addresses and contacts with various citizen and special-interest groups.

210. Citizens' advisory committee. The form of a citizens' advisory committee and its delegated responsibilities will vary from situation to situation depending on the degree of public interest and posture of elected local officials. The amount of direct citizen control over the project can range, theoretically, from none to complete control of all decision making. Degrees of control from Adkins and Burke (1971) include:

1. Manipulation. Citizens are placed on advisory panels or otherwise used to suggest that "grass roots" people are involved in the decision-making process.

2. Information. Citizens are informed of the plans, their rights, and options. Often this is a one-way information flow from officials to citizens. News media, pamphlets, posters, and response to inquiries are methods used to transmit information.

3. Consultation. Attitude surveys, neighborhood meetings, and public hearings provide data and information to the officials, but no authority is obtained by the citizens.

4. Placation. Citizens have some degree of influence. Placement of citizens on planning boards and study

teams, where the officials are in the majority, keeps decision making in the hands of the officials.

5. Partnership. Authority is shared by citizens and officials using joint policy boards, planning committees, and mechanisms for resolving impasses.

6. Delegation of authority and citizen control. Final approval of projects cannot be achieved without the consent of the represented citizen groups.

211. Experience suggests that citizen advisory boards or committees should be limited to no more than ten individuals. Meetings ought to be scheduled to ensure attendance. The summer months should be avoided if possible; public dedication goes only so far, and vacations can disrupt planned meetings.

212. Whatever the form, the duties of such a group should be multiple. Members should work with other responsible parties to create a work plan, participate in the site survey and selection, and encourage public education efforts. The existence of this group also has important spin-off effects: it sharpens the proponents and their consultants and requires that all "homework" be done before committee meetings.

213. A specific plan for general public involvement should be developed. Such a plan will include a public information and education program and defined methods, enabling citizen input and feedback.

214. Communications media. The mass media may be helpful in disseminating general information through articles, special features, and interviews. Additionally, the mass media should be utilized for notification and advertisement of hearings and other public meetings.

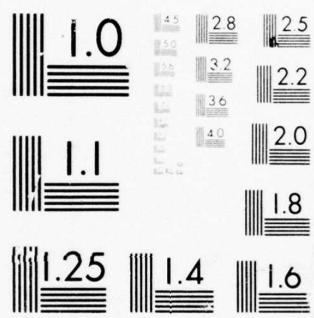
215. Films on dredged material disposal can be shown to specific civic groups and the public at large. Group discussions can follow film showings, thus providing a useful means of answering questions which concern residents, with knowledgeable professionals leading the discussion to ensure correct responses.

216. News releases should be sent to the media often. Releases to newspapers should be coordinated with publicity sent to television and radio stations and community association newsletters. In addition, brochures, handouts, and fact sheets should be distributed to the media

AD-A048 203 SCS ENGINEERS LONG BEACH CALIF F/G 13/2
FEASIBILITY OF INLAND DISPOSAL OF DEWATERED DREDGED MATERIAL: A--ETC(U)
NOV 77 DACW39-76-C-0121
UNCLASSIFIED WES-TR-D-77-33 NL

2 OF 2
ADI
A048203

END
DATE
FILMED
1 -78
DDC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

to acquaint them with the issues and keep them informed of the project's progress. Before a story is to be issued, the news media should be contacted to explain the advantages and disadvantages of the available sites, the costs of each, and the sources of opposition and support. If the planned final use of the site would directly benefit the public (a park, for example), final use plans should be prominently noted.

217. Public hearings. Public hearings, which are required for most large public works projects like a dredged material disposal site, allow individuals and representatives of groups to speak and present written statements of their viewpoints. Notification of the hearing should be extensive and, in addition to advertisements in the mass media, should include notification by mail to all groups, agencies, and individuals who may have an interest. To ensure that key decision makers are present, personal telephone invitations may be necessary. The hearing should be followed up by resolution of disagreements, corrections of deficiencies, additional hearings, or any other measures that may be necessary.

Social Impact Evaluation

218. The overall effects of the proposed site should be evaluated in light of its impact on the sociological aspects of the community. Included in the evaluation should be considerations of possible need to relocate residents, effects on greenbelts and open space, effects on recreation activities, effects on community growth, and effects on the quality of life.

Relocation of Residents

219. The requirement for large tracts of land often necessitates the purchase of land and the possible relocation of residents. For federally funded projects, the acquisition of land and relocation of residents must be conducted in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. In such cases, the advantages of the proposed site must be weighed against the

inconvenience caused affected residents and then compared with other alternatives.

Greenbelts and Open Spaces

220. The proposed site should be evaluated from an aesthetic point of view and with respect to the creation or destruction of greenbelts and open spaces. Disruption of the local scenic character is often unnecessary and always undesirable. On the other hand, proper site design and planning can often enhance the beauty of the landscape. Reforestation and reclamation of disturbed areas, such as those resulting from strip mining operations, are possible beneficial effects.

Recreational Activities

221. The impact of the disposal site on recreational facilities should be considered. Existing open space or parks may be disrupted; however, other recreational areas may be created or upgraded. Site development should be planned to minimally disrupt existing recreational areas, thereby minimizing possible adverse public reaction from this source.

Community Growth

222. Development of the site may stimulate or discourage community growth in terms of economics and population. Such growth may consequently tax other existing community services. The potential of the disposal site for affecting community growth should be evaluated, and the subsequent effects on other aspects of the community documented.

CHAPTER 8: INSTITUTIONAL CONSTRAINTS AFFECTING THE FEASIBILITY OF INLAND DISPOSAL

223. Regulations and statutes applicable to any inland dredged material disposal site may include those laws governing solid and semisolid waste disposal on land in general and dredged material disposal activities specifically (Lee et al. 1976 and Wakeford and Macdonald 1974).

224. The DMRP (Wakeford and Macdonald 1974 and Lee et al. 1976), Harrison and Chisholm (1974), the State of California (1976), the U.S. Department of Commerce (1976), and Smith (1976) list regulations governing dredging projects. The EPA (Lehr et al. 1976) has prepared a manual of Federal and State laws regulating waste disposal on land. The following section briefly summarizes those regulations reported in the literature. The original texts should be reviewed for complete regulations. Also, State environmental agencies should be consulted for specific laws governing land disposal activities within their jurisdictions.

Dredging Regulations

225. Table 10 lists the primary laws governing dredging activities and the agencies administering them. It should be noted, however, that research on dredging and disposal activities will probably be the basis for significant changes in regulations (U.S. Dept. of Commerce 1976).

226. The Federal government has regulated dredging activities for over 75 years. The Federal Rivers and Harbors Act of 1899 gave the CE permit jurisdiction over dredging activities. The Federal Water Pollution Control Act (FWPCA) of 1972, Public Law 92-500, Section 404, has increased that jurisdiction. The CE permit application and processing procedures are described in Wakeford and Macdonald (1974) and Smith (1976). In recent years, however, as public awareness of environmental issues and resource management has become more prominent, both

Table 10

Primary Laws and Agencies

Act	Responsible Agency
Rivers and Harbors Act of 1899	U.S. Army CE
Federal Water Pollution Control Act of 1972	EPA U.S. Army CE State Water-Quality Agencies
Fish and Wildlife Coordination Act of 1958	U.S. Fish and Wildlife Service State Fish and Wildlife Agencies
National Environmental Policy Act of 1969	All Federal agencies whose actions affect the human environment
Coastal Zone Management Act of 1972	Designated State Coastal Zone Management agencies through the Federal Office of Coastal Zone Management
State and local laws and ordinances governing land use, public works, material resources, health, etc.	State and regional land use planning agencies, natural resources agencies, and numerous local government units

the Federal and State governments have increased their participation in the regulation of dredging. The result has been a closer scrutiny of dredging projects (State of California 1976).

Water Quality

227. Of all the Federal and State laws stating public policy, water-quality requirements are the most pervasive (Lee et al. 1976). Land disposal of polluted dredged material and its impacts on water quality are controlled by those laws regulating other wastes disposed

of on land. State programs must conform to Section 402 of the FWPCA and generally require an application for discharge of materials (State of California 1976). Section 404 of the FWPCA requires the EPA acting in conjunction with the CE to develop guidelines for the disposal of dredged material (Federal Register, Sept. 5, 1975, Vol. 40, p. 41292, 1975c, and U.S. EPA Region IX, "Dredge Spoil Disposal Criteria," 1975a).

Environmental Impact Requirements

228. The National Environmental Policy Act of 1969, 42 U.S.C. 4321, et seq., requires the preparation of an Environmental Impact Statement (EIS) when proposed legislation or other Federal actions may significantly affect the human environment. Accordingly, the environmental impact of land application of polluted dredged material, including public health, social, and economic aspects, should be addressed. Similar reports and surveys are required by many State and local governments for State, local, or private actions affecting the environment (Lee et al. 1976). Criteria for assessing the environmental impact of land disposal of dredged material are presented by U.S. Army Engineer District, San Francisco (1974).

Terrestrial Animal Life Regulations

229. The Federal Fish and Wildlife Coordination Act, 16 U.S.C. 661, et seq., requires the CE to consult with the U.S. Fish and Wildlife Service and the head of the appropriate State agency concerned with wildlife resources before issuing a dredging permit. The CE and the Dept. of the Interior have a cooperative agreement, "Memorandum of Understanding," 40 Fed. Reg. 17023, pledging mutual cooperation and binding the CE to consider fish and wildlife conservation, pollution, aesthetics, ecology, and the general public interest in acting on permits (State of California 1976).

Land Disposal Regulations

230. Federal, State, and local ordinances have been established nationwide regulating land disposal of wastes. Disposal of polluted dredged material may often be regulated by these ordinances. The

regulations are generally related to pollution control and public health and safety. The site sponsor must be aware of all applicable regulatory requirements. Most states have statutes that prohibit disposal of waste without a permit from either a local or State agency. The statutes typically authorize a State agency to adopt regulations and leave it to the adopting agency to set requirements for the various conditions that may exist (Lehr et al. 1976). The permit will likely contain specific requirements governing site development such as groundwater and gas monitoring by means of test wells in the vicinity of the site (American Society of Civil Engineers 1976).

231. Typical regulations cover information and other requirements for permit acquisition and site selection, as well as specifications concerning proximity of water resources and prohibited types of disposal. Construction, equipment, operation, reporting, monitoring, and closing requirements are also covered.

Information and Other Requirements for Obtaining a Permit

232. Information typically required prior to issuance of a permit reported in Lehr et al. (1976) may include:

1. *Plans and specifications* for the proposed disposal site. Some States require that these be prepared by a registered professional engineer.
2. A map or aerial photograph of the area showing land use within the adjoining area. Locations of water wells may be required.
3. A report on geologic formations and soil conditions including depth to groundwater. Various State regulations require data describing soil classification, grain-size distribution, permeability, compactability, and ion-exchange properties of the subsurface materials for those strata essential to design of the site; comprehensive analysis of water samples from on-site and nearby wells; and a description of groundwater conditions including flow below and adjacent to the proposed site, with an appraisal of the effect of the disposal on groundwater and surface waters.
4. A description of surface drainage patterns. For example, California regulations require calculations for the flooding frequency of streams within or adjacent to the site.

5. A report of:

   a. Anticipated type, quantity, and source of dredged material.

   b. Source and characteristics of cover soil.

   c. Type and number of equipment units and operating plans.

6. Information concerning measures proposed for prevention of water pollution and for control of drainage, leachate, and gases.

233. Frequently, the statute or regulation will require that a representative of the regulating agency inspect the site prior to issuance of a permit. Some regulations also require a statement or plan as to ultimate use of the site after closing.

234. Highly polluted dredged material may be classified as hazardous. Special provisions for hazardous waste disposal are contained in many State statutes. Well-defined statutes include those of California, Wisconsin, and Oregon.

235. The California regulation controls disposal of hazardous wastes by its system of categorizing types of disposal sites, wherein only the "Class I" site may receive such wastes (State of California 1976). Requirements for such a site are strict; there can be no possibility for liquids to reach water resources either downward or through inundation or washout.

236. The Wisconsin regulation applies special provisions to toxic and hazardous wastes, including quarterly reports of the quantities and types of such wastes disposed of at the site during the previous calendar quarter. It also requires that wells be provided at locations specified by the department and that samples from these wells be collected and analyzed quarterly (Lehr et al. 1976).

237. The Oregon statute requires that an applicant for a permit to operate a waste disposal site receiving "environmentally hazardous wastes" must, as a condition of the permit, convey the land to the State. The statute prohibits disposal of hazardous wastes on land other than that owned by the State (Lehr et al. 1976).

238. If there is any question of the acceptability of a material for land disposal, appropriate State environmental agencies should be contacted. Those agencies will be able to provide the necessary clarification and interpretation of the State's regulations and statutes.

Other Requirements in Waste Disposal

239. Various regulations may contain requirements for operation of disposal sites, such as method of filling, placement of impermeable barriers, grades, method of confining wind-blown material, and requirements for fences, roads, signs, and screening by vegetation. The statutes or regulations typically require that dust, insects, and vermin be effectively controlled.

240. Regulations frequently require that surface drainage be diverted from the working area. Some regulations require that surface runoff from a site be suitably treated to comply with water pollution control standards. A number of regulations require installation of monitoring wells but leave specific site requirements to the administering agency.

241. Upon closing a disposal site, seeding, contouring, and other reclamation-type work are often required. The Wisconsin regulation requires installation of monitoring wells and water-quality sampling and analysis after the site is closed. The Model State Solid Waste Management and Resource Recovery Incentives Act of the Council of State Governments, 1972, proposed a requirement that all persons operating under permit be required, upon completion of their waste disposal site, to file a plat of the site with the county recorder, together with a description of the waste placed therein (Lehr et al. 1976). If the Act is imposed, it can be expected that dredged material disposal sites will be required to comply.

242. Recent concern for noise pollution is manifested by EPA Office of Noise Abatement and Control (1974 and 1975), which sets noise standards to protect public health and welfare. Occupational Safety and Health Standards specify acceptable noise levels for affected employees. State codes should be consulted for requisite acceptable noise levels during disposal operations.

Federal Guidelines

243. EPA has prepared Solid Waste Management Guidelines (EPA 1974b) for the disposal of municipal waste under directive of the 1970 amendments to the Solid Waste Disposal Act of 1965 (Public Law 89-272). The guidelines represent the judgment of the EPA regarding what is necessary to ensure both environmental protection and satisfactory and acceptable design and operation of land disposal facilities. They are intended to be achievable using current technology, while providing flexibility for unique and specific climatological, geological, geographical, and related conditions. The guidelines are recommended for adoption by State and local governmental agencies; they are mandatory for Federal agencies and for waste disposal on Federal lands. Land application of polluted dredged material will likely be subject to legal constraints imposed on land application of solid and semisolid wastes (Lee et al. 1976).

Land Use Regulations

244. Several states have enacted statewide land use laws with general objectives of requiring wise development and preservation of natural resources. The statutes typically include provisions for the protection of water quality. Land use requirements, as in local zoning, may prohibit locating disposal sites in a floodplain or over thin permeable strata where the likelihood of groundwater pollution is unreasonably high (Lehr et al. 1976).

245. Planning provisions established by the appropriate authority must be consulted. The status of any formal master plan for the area must be determined. A land use master plan may preclude the use of what may, from other points of view, appear to be a suitable site. Besides existing zoning regulations, the likelihood of future changes in zoning must be considered. The ultimate use proposed for the completed site should be considered at the earliest phases of site selection and must be compatible with the natural character of the area and the provisions of the master plan. The present and future zoning

and use of the lands adjacent to the proposed site will also influence the selection (American Society of Civil Engineers 1976).

246. Areas of historical and archeological significance are protected by Federal statutes (Section 106 of the National Historical Preservation Act of 1966 (6 U.S.C. 470 (f)) and Executive Order 11593 of May 13, 1971). The Advisory Council on Historic Preservation must have evidence that the most recent listing of historical places has been consulted ("National Register of Historical Places" 1974). Substantial alteration of National Register Properties must comply with Executive Order 11593.

CHAPTER 9: FINAL SITE USE AFFECTING THE FEASIBILITY OF INLAND DISPOSAL

General Considerations

247. Final uses for completed dredged material and land disposal sites are reported by U.S. Army Engineer District, San Francisco (1974), American Society of Civil Engineers (1976), Arthur D. Little, Inc. (1975), Mann et al. (1975), Skjei (1976), and Lee et al. (1976). The final use of a dredged material disposal site offers an opportunity to gain land for a permanent beneficial purpose. Final use features should be designed concurrently with the disposal operation since decisions regarding final use can substantially affect operations. Each step of the disposal process (initial site preparation, installation of monitoring and control facilities, placement of dredged material, final cover, and revegetation) should be performed as steps toward achieving the final use plan.

248. Deposition of dredged material on inland sites has an effect on the ultimate suitability of the site for a variety of potential uses. Dredged material can cause significant changes in various site physical parameters. Most changes can be mitigated or significantly altered either during the active life of the disposal site or subsequent to complete utilization of its disposal capacity.

249. Because of this influence on the physical characteristics of the site, the disposal operation has the potential for materially influencing both public and private decisions concerning final land use. Thus, it is important that the location of a disposal site be compatible with currently existing and anticipated land use plans. By proper planning, with respect both to site location and disposal techniques, it may be possible for disposal operations to be of direct benefit to the socio-economic condition of an area. Conversely, inadequate planning could lead to disposal practices that are detrimental to the area (U.S. Army Engineer District, San Francisco 1974).

250. Land disposal sites have most often been reused for open space. Recreation, conservation, and agricultural uses are also

compatible. However, because of the unique problems of low bearing capacity and settlement, industrial and community uses may be made only under carefully controlled conditions. If there is existing open land or a buffer zone surrounding the fill area, almost unlimited use can be made of the undisturbed area, and the fill area may be developed for a complementary open space use.

Engineered Fill

251. If filled areas are designated for eventual urban development, it is likely that the deposited material can be handled in such a way that its load-bearing and other physical characteristics are optimal from an engineering standpoint. Physical properties that are desirable from an engineering standpoint may be diametrically opposed to the characteristics that would be most advantageous to agriculture (U.S. Army Engineer District, San Francisco 1974).

Open Space

252. A dredged material disposal site could be made compatible with a variety of open space options, including park and recreation areas and wildlife habitat. The suitability of a filled disposal site will be a function of the physical, chemical, and biological effects of the disposal operation and the dredged material on the site. Thus, it will be necessary to determine what kind of final open space use is anticipated before filling procedures are begun.

253. An inland dredged material disposal operation ensures the availability of land at a predictable future date. Since this land can be used productively as open space after disposal operations are completed, close coordination with local planning agencies and other local interests concerned with land use is desirable. This coordination can result in the completed disposal site being integrated into a well-conceived total land use and open space plan at an early date (U.S. Army Engineer District, San Francisco 1974).

Agriculture

254. The following are examples of measures which might facilitate agricultural production on a completed site:

1. During the site-preparation phase, native top soil could be removed and stockpiled, to be spread over the material at the end of the site's life.
2. The fertility or productivity of the dredged material could be improved by both physical means and chemical additives.

(U.S. Army Engineer District, San Francisco 1974).

Buffer Zones

255. Dredged material disposal may have some value in creating buffer zones between otherwise adjacent incompatible uses. For example, it may be desirable to locate a disposal operation between natural wildlife areas and encroaching urban development. Further, the site may have, during the filling operation, a certain utility as wildlife habitat of marginal though perhaps significant value. Upon completion of filling, provision could be made for more permanent features to restrict or control access to or across the site in perpetuity (U.S. Army Engineer District, San Francisco 1974).

Land Planning Study

256. The selection and design of final land uses should be the result of a comprehensive land planning study (American Society of Civil Engineers 1976) which considers all aspects of the proposed disposal operation as well as final uses. Objectives of a land planning study should be to identify uses which will:

- Optimally utilize permanent disposal site improvements.
- Eliminate or minimize potential conflicts with off-site developments.
- Minimize the area disrupted by disposal activity at any one time.

- Help meet future needs of the community.
- Be compatible with existing natural conditions and activities.

The land planning process should be totally integrated with site selection. Four important steps to follow in the planning process are indicated below.

Determine Needs

257. Future conditions at the site and surrounding area may be determined by an examination of the general master plan, area master plans, the master plan of highways, utility plans, population projections, projected demand for recreation and public facilities, the capital improvements program for parks and other public facilities, the physical characteristics of the site during and after the disposal operation, and the anticipated life of the site. Public officials and agencies responsible for planning in the area should be contacted to review the potential final uses of the selected site.

Identify Possible Uses

258. From the information on existing and proposed facilities and the future demand for these facilities, a list of anticipated deficiencies in open space for recreation and public and private uses should be developed for the vicinity. The final use would likely be designed and developed for diversified use by people from the entire area. In some rural settings, the use may be agricultural if characteristics of the dredged material warrant. In other instances the best practical final use may be as industrial land, again dependent on dredged material characteristics and demand for such land use.

Program the Final Use Opportunities

259. Having identified the future needs of a community, the physical opportunities and constraints of the site should be examined to identify final uses which are compatible and complementary to the existing conditions. Features on land adjacent to the filled area such as attractive natural streams, vegetation, vistas, and linkages to surrounding parks or other public facilities can strongly influence the type of use suitable for a filled parcel.

Consider Land Design

260. After inventorying the site features and those of the surrounding area, and after developing a preliminary land use program, detailed planning and design of the site can be initiated. Design of final uses for a dredged material disposal site should reflect unique constraints and opportunities in addition to conventional planning factors. Since a disposal operation inevitably involves a major reshaping of landforms, the changes which occur can be regarded as an opportunity to restructure the site for a predetermined final use. Landforms may be designed to complement or contrast with existing topography and must be selected to augment the use of the area.

261. Plantings of vegetation in fill areas must be carefully selected to match depth of earth cover available and dredged material characteristics with plant characteristics. Areas designated for deep-rooted plants and trees will require more cover than areas planned for grass or shrubs. Existing trees on a site are a valuable asset if the fill can be designed to preserve them, since they will provide some screening during the disposal operation, and, when completed, the site will have a more mature appearance than if all new landscaping must be established. Special technical assistance is usually required when preparing a detailed revegetation plan to recognize the variables that affect growth. The local agricultural extension service, Soil Conservation Service office, and other similarly oriented agencies are potential sources of such assistance. Sometimes the disposal area can be systematically prepared to permit early reuse of completed portions of the site. It should be emphasized that continual maintenance will be required upon completion of the site to compensate for any settlement, surface cracking, or other changes that may occur, or else vegetation may not establish well or may die.

CHAPTER 10: CONCLUSIONS AND RECOMMENDATIONS BASED ON LITERATURE REVIEW

262. Based on a review of existing information related to dredged material and solid waste disposal, the following conclusions and recommendations are presented concerning the feasibility of implementing dredged material disposal at inland sites.

Conclusions

263. Information on the inland disposal of dredged material is currently insufficient to quantitatively evaluate the feasibility of inland disposal activities.

264. Many of the impacts of inland disposal of polluted dredged material would be similar to those encountered from land disposal of solid and semisolid wastes. Consequently, information developed from studies of land disposal of solid waste and sludge is partly transferable to the assessment of impacts of polluted dredged material disposed of on land.

265. A properly designed and operated inland disposal site for dredged material can be environmentally and socially compatible with the surrounding area.

266. A checklist developed for the study provides a framework for selecting environmentally and socially acceptable dredged material disposal sites that cost-effectively meet project needs.

267. Potential environmental problems associated with polluted dredged material transportation and disposal include:

1. Leachate production and associated water pollution.
2. Vector breeding and habitat.
3. Odor.
4. Noise.
5. Aesthetics.
6. Air pollution and dust.

7. Importing foreign contaminants into an area.

8. Public health and safety.

268. Controls can be implemented to mitigate environmental pollution. Both short- and long-term pollution problems must be defined a priori so that a comprehensive monitoring plan may be formulated.

269. After deposition of dredged material, an inland disposal site should be returned to a condition compatible with the surrounding environment and be vegetated for stabilization and erosion control.

270. Final use of an inland dredged material disposal site offers an opportunity to gain land for beneficial purposes. Each step of the disposal process should lead toward achieving the final use plan.

271. Development costs for an inland dredged material disposal site include capital, operating, environmental monitoring and protection, and transportation costs. These costs are site-specific and depend on material volumes, material transport mode selected, need for access road construction, types of equipment used, site topography, prevailing labor wage rates, and land costs.

272. Establishment of land disposal sites is often opposed by the public. Public support for dredged material inland disposal projects should be nurtured through proper planning, implementation, and management. A public information and possibly a participation program can help define disposal project plans and win public support.

273. Regulations and statutes applicable to any inland dredged material disposal site may include all those laws governing land disposal of solid and semisolid waste in addition to those dealing specifically with dredged material disposal activities.

Recommendations

274. The CE should continue the present program of research on leachate production potential from inland disposal of dredged material.

275. One or more detailed case studies of past experiences with inland disposal should be prepared. Ideally at least one successful effort and one problem site would be studied. Features from each

situation would be compared and contrasted. Information from such a study would help CE District personnel plan successful implementation of inland dredged material disposal.

PART III: CHECKLIST FOR DETERMINING POTENTIAL INLAND DISPOSAL SITES

Purpose

276. Federal, State, and local regulations reflect increasing public concern for environmental and social impacts associated with any public works action. Consequently, location and operation of areas for disposal of dredged material require careful planning. This checklist is presented for use by decision makers who must provide final disposal of either polluted or nonpolluted dredged material. Intended users of the checklist include: CE, port authorities, NAVFAC, EPA, and State and local agencies responsible for water pollution control, public works, planning, solid waste management, and wildlife management.

277. The checklist is designed for a "worst case" situation in which the dredged material is highly polluted and covers all possible factors that must be evaluated in selecting an environmentally and socially acceptable disposal site.

278. In many cases, however, dredged material is a resource which can enhance an area when properly disposed. The checklist facilitates selection and implementation of such a site which ultimately can be used for a beneficial purpose. Only checklist areas applicable to each specific situation need be completed. Generally areas such as public opposition, noise and similar impacts, wildlife protection, and economics are independent of the type of material to be disposed. The checklist covers all possibilities that may exist.

279. Local, State, and Federal agencies requiring a systematic plan for disposal of dredged material because of existing regulations will find the checklist suited to their needs. Again, the checklist will provide a comprehensive evaluation of all factors necessary for proper disposal site planning.

280. If the disposal site has been properly selected to ensure protection of the environment and is accepted by the public, future reuse of the site will be assured.

281. Use of the checklist can assist officials by providing:

- A rational means for selection of environmentally acceptable dredged material disposal sites that cost-effectively meet project needs.
- A framework for development of a project plan that incorporates all requisite considerations before major actions are undertaken.
- A guideline that can help identify what subjects require significant effort, thus aiding in the budgeting of available time and manpower.

Checklist Description

282. The checklist is divided into three sections which together identify a broad range of project and disposal site information to be collected and reviewed. The flow chart included as Figure 9 illustrates the checklist organization and the interrelation among the sections.

Section A

283. Section A provides a format for gathering general information about the dredging project. It is also used to list candidate final inland disposal sites.

Section B

284. Section B develops site-specific background data for each candidate final site identified in Section A. Section B explores six basic categories relating to the feasibility of site use for the disposal of dredged material. These categories are:

1. Land use information and institutional constraints.
2. Physical features.
3. Technical considerations.
4. Environmental and social impacts.
5. Public attitudes.
6. Economic factors.

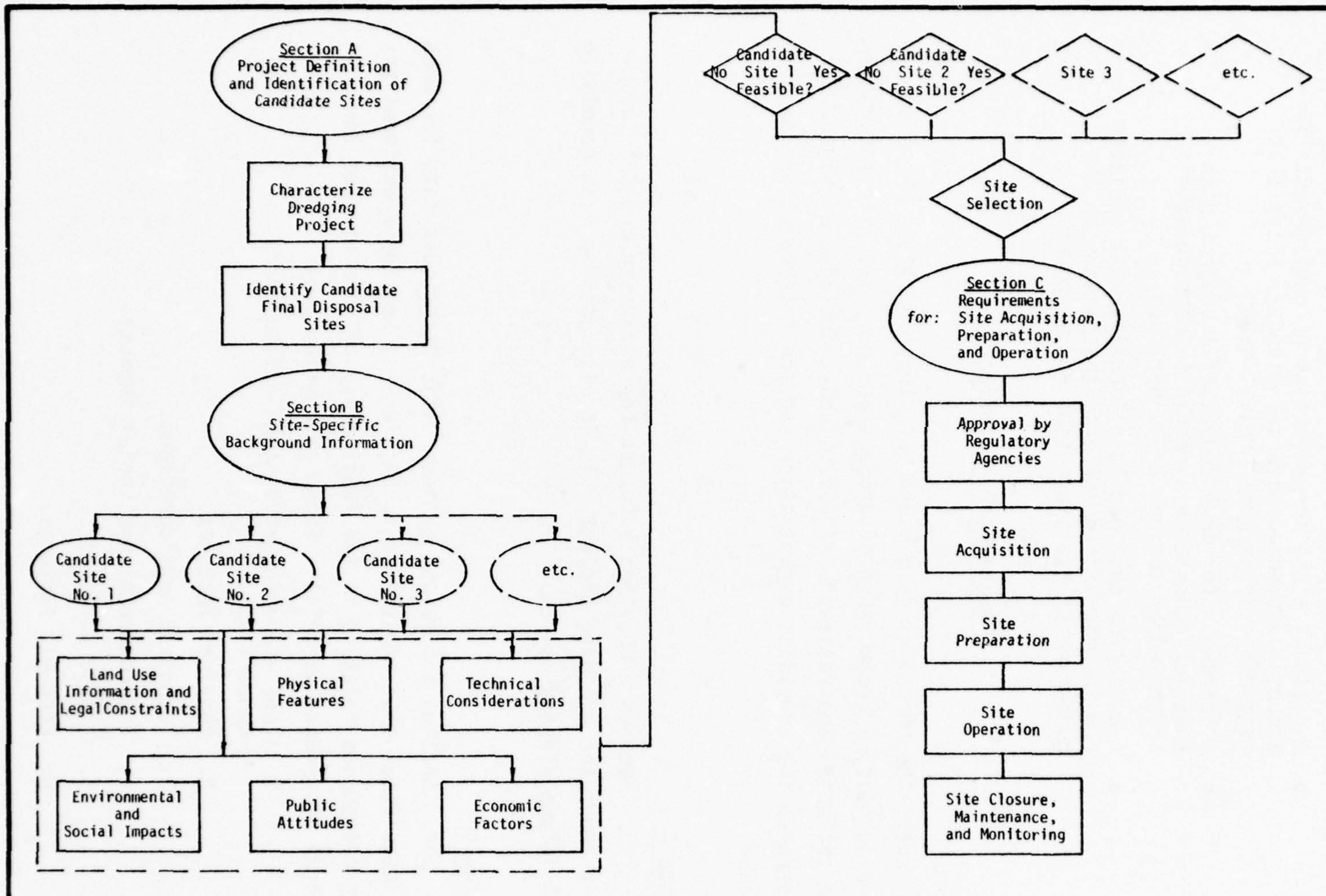


Figure 9. Checklist organization.

285. It is anticipated that use of Section B will generate a list of viable candidates for disposal sites from which selection of one site (or several) can be made by decision makers. A separate copy of Section B should be completed for each candidate site. These would form a formal document concerning the sites that can be used to support the site selection decisions and provide a head start when next evaluating disposal sites in the same area.

Section C

286. Section C outlines the requirements for acquisition, preparation, and operation of the selected site. It is comprised of the following five considerations:

1. Government agency approval.
2. Site acquisition.
3. Site preparation.
4. Site operation.
5. Site closure and future site use.

Checklist Usage

287. The checklist addresses various aspects of candidate site identification and selection. Included are considerations necessary to design, prepare, operate, and monitor the selected site. Although each of the factors in Section B is an essential site-selection criterion, checklist users individually must decide the relative importance of each factor for the specific site being considered.

288. Clearly, some of the criteria, such as potential environmental and social impacts, will of necessity be qualitative. Technical or economic considerations can be more precisely defined. Still other constraints such as State water-quality regulations are inviolable. Factors such as anticipated public attitude can be measured under today's conditions but are subject to significant change in the future. Thus, use of information compiled by the aid of this (or any) checklist should be adapted to specific conditions at the site(s) in question and project timing and needs.

289. In the end, decisions as to inland disposal sites selected and operating procedures implemented will rely on the educated judgement of decision makers. The checklist serves as a means of enhancing that judgement by making available thorough, accurate information to the decision makers.

Section A: Project Characterization and Identification of Candidate Sites for Final Inland Disposal of Dredged Material

I. Characterize Dredging Project (include appropriate maps)

A. Locations:

Dredging activity(ies) ______________________________

____

Intermediate rehandling site(s) ______________________________

____

B. Materials handling description

Dredged material received or expected	Initial disposal site	Final disposal site
1. Characteristics		
a. Daily volume (est. cu yd/day)	______	______
b. Soil classification (USCS)	______	______
c. Permeability	N/A	______
d. Organic content (%)	______	______
e. Chemical constituents	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______

Section A (Continued)

	Initial disposal site	Final disposal site
2. Transportation		
a. Method (rail, barge, truck, conveyor)		
b. Distance from initial disposal site	N/A	
c. Frequency of delivery		
d. Volume/delivery (cu yd)		
3. Disposal operations		
a. Method (type of dredge)		N/A
b. Rate of disposal (cu yd/time)		
c. Frequency of disposal operations (e.g., twice/yr, continuous, etc.)		
d. Duration (e.g., 2 months at a time, etc.)		
e. Season(s) of year		
4. Site capacity required		
a. Total volume (cu yd)		
b. Planning period (years)		

II. Identify Candidate Final Inland Disposal Sites

A. Existing sites

1. Sites with additional capacity
2. Sites where expansion is possible (by extra area, dike raising, etc.)
3. Sites where previously disposed material could be removed (e.g., sale of material)

Section A (Continued)

B. New sites - suggested information sources are:

1. Remote sensing (e.g., aerial photographs, ERTS mosaics, false infrared imagery, etc.)

2. Maps from government agencies (e.g., USGS, USDA, NOAA, ASCS, planning agencies, highway departments, etc.)

3. Requests to:

    a. Local and State government representatives

    b. Private organizations, businesses, realtors, and individuals

C. Tabulate candidate sites identified (form follows on next page)

Section A (Concluded)

Candidate Sites

Candidate No.	Site Name	Map reference code	Location: Municipality	Location: County	Location: State	Area (acres)	Estimated capacity (million cu yd)
(Example)							
1	Ridge	A-35	Anytown	Alber	KY	82	11.8

Section B: Site-Specific Background Information*

Candidate Site Number ____________________

Site Name ____________________

Location ____________________

Map Reference Code ____________________

I. Determine Relevant Land Use Information and Institutional Constraints for This Site:

	On-site	Adjacent property or vicinity
A. Property owner(s)	________	________
	________	________
1. Address	________	________
2. Telephone No.	________	________
	________	________
	________	________
	________	________
	________	________
	________	________
	________	________
	________	________
	________	________
B. Land use		
1. Previous		
a. Recent past	________	________
	________	________
b. Archaeological & historical significance	________	________
	________	________
2. Present	________	________
	________	________

*Note: One set of this form (Section B) should be completed for each candidate disposal site.

Section B (Continued) Site No. ______

	On-site	Adjacent property or vicinity
3. Projected		
a. Without dredged material disposal area	______	______
b. As dredged material disposal area	______	______
c. Long-term (after termination of disposal operations)	______	______

C. What existing improvements would require relocation?

	On-site	Adjacent property or vicinity
1. Utilities	______	______
2. Pipelines	______	______
3. Roads	______	______
4. Residences	______	______
5. Other structures	______	______

D. Could site used as dredged material disposal area conform to:

1. Area (county/municipal) land use plan? yes ____ no ____
2. Zoning regulations? yes ____ no ____

   If not, are variances or special permits available? yes ____ no ____
3. Pollution control requirements?
   a. Federal yes ____ no ____
   b. State yes ____ no ____
   c. Local yes ____ no ____

Section B (Continued) Site No. ____

E. Anticipated land trade-off requirements ____________________

____

F. Comments ____

____

G. Based on land use information and legal constraints, site use for disposal of dredged material would likely be:

1. Feasible _____

2. Uncertain _____

3. Not feasible _____

II. Characterize Physical and Chemical Features of This Site

A. Soils

1. Permeability of on-site soils ____________________

____

2. Soil profile (USCS) (i.e., 0-3' , 3-10', etc.) _________

____

____

____

3. Soil pH ____

B. Subsurface hydrology

1. Existence of aquifer beneath site? yes ____ no ____

2. What kind?

a. Artesian _____

b. Unconfined _____

3. Estimated range of depths to aquifer ____________________

4. Provide available water-quality data (water pH= _________)

Constituent	Concentration	Constituent	Concentration

Section B (Continued) Site No. ____

5. Is nearby water used for:
   a. Drinking yes ____ no ____
   b. Irrigation yes ____ no ____
   c. Industrial cooling yes ____ no ____
6. Direction of groundwater flow ____________________
7. Fluctuations in groundwater depth ____________________
8. Distance to nearest wells using aquifer:
   a. Upstream of site ________________
   b. Downstream of site ________________
   c. Site location related to cone of depression ____________
9. Is site in either:
   a. Discharge area yes ____ no ____
   b. Recharge area yes ____ no ____

C. Geologic conditions

1. Any outcrops visible on site? yes ____ no ____
2. Dominant geologic features on site: (i.e., hill, sink, depressions, etc.) ____________________

   ____

   ____
3. Slope of site: $<1^{o}$ ____ 5^{o} ____ 10^{o} ____ $>15^{o}$ ____
4. On-site landslide or slumpage potential ________________

   ____

   ____
5. Subsurface geology: Description of subsurface formations, depth to bedrock, etc. ____________________

   ____

   ____
6. Seismic data
   a. Presence of on-site fault ____________________
   b. Location of fault ____________________
   c. Date and magnitude of fault activity, if any ________

   ____

Section B (Continued) Site No. ___

D. Topography

1. Is candidate site subject to:

a. Periodic flooding yes ___ no ___

If so, what frequency (e.g., 50-year flood plain?) ________________

b. Ponding yes ___ no ___

E. Surface waters

1. Are there on-site:

a. Springs yes ___ no ___

b. Streams yes ___ no ___

c. Ponds yes ___ no ___

d. Lake yes ___ no ___

2. Distance to nearby surface waters

a. Upstream ________________

b. Downstream ________________

3. Uses of these waters

a. Upstream ________________

b. Downstream ________________

4. Provide available water-quality data (pH = ________)

Constituent	Concentration	Constituent	Concentration

F. Vegetation

1. Description of on-site vegetation ________________

____

Section B (Continued) Site No. ____

2. Description of surrounding vegetation ________________

____

G. Fauna

1. Description of on-site fauna ________________________

____

2. Description of surrounding fauna (habitats) __________

____

H. Climatological data (use average data from past records)

1. Evaporation rate (in. per year) ____________________
2. Transpiration rate (in. per year)* __________________
3. Rainfall (in. per year) ________________________
4. Snow (in. per year) __________________________
5. Temperature range (annual maximum - minimum) __________

____

6. Prevailing wind direction and velocity ______________

I. Comments ________________________________

____

J. Based on the physical features, site use for disposal of dredged material would likely be:

1. Feasible _______
2. Uncertain _______
3. Not feasible _______

III. Describe Technical Considerations for This Site

A. Site accessibility

1. Identify existing access (sketch on area map)

a. Paved roads: identify (e.g., US30) _____ width _____

% grade ______ bearing capacity ______

b. Unpaved roads: identify _____ width ______

% grade _____ bearing capacity ______

surface characteristics ____________________

*Estimated on basis of types of vegetation.

Section B (Continued) Site No. ____

c. Rail: identify _______

d. Canal: identify _______ width _______

depth _______ navigable months ____________________

e. River: identify _______ width _______

depth _______ navigable months ____________________

f. Belt conveyor: identify _______ capacity _________

B. Suitability of soils for construction

1. Are acceptable soils available? (yes or no)

____

For \ From	On-site borrow area	Borrow area on nearby property	Dredged material
a. Construction of earth berms	_______	_______	_______
b. Impermeable site liners	_______	_______	_______
c. Cover material	_______	_______	_______
d. Construction of access roads	_______	_______	_______
e. Under-drainage for leachate collection	_______	_______	_______

2. Bearing strength of site subbase is sufficient to support:

a. Desired slopes of excavations and landscape modifications. yes ____ no ____

b. Weight of dredged material without excessive settlement. yes ____ no ____

C. Comments ____

____

____

____

Section B (Continued) Site No. ____

D. Based on technical considerations, site use for disposal of dredged material would likely be:

1. Feasible _______
2. Uncertain _______
3. Not feasible _______

IV. Assess Potential Environmental and Social Impacts of This Site

Prediction of future impacts of dredged material disposal activities is necessarily a subjective endeavor. The checklist below is intended to help the evaluator rate the severity of potential impacts.

Instructions. The evaluator should check the blank or parentheses under the appropriate column for the "anticipated magnitude of impact." Then the appropriate box should be marked to indicate the expected overall impact on the particular major category (designated by capital letters).

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
Impact			
A. Groundwater quality	☐	☐	☐
Factors			
1. Leachate production & potential migration to groundwater	_____	_____	_____
2. Water table fluctuations which can result in leachate production	_____	_____	_____
3. Intense or extended precipitation resulting in leachate production	_____	_____	_____

Section B (Continued) Site No. ____

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
<u>Impact</u>			
B. Surface water quality			
<u>Factors</u>			
1. Surface erosion and runoff from disposal site to surface water	____	____	____
2. Overtopping of containment structure resulting in increased erosion	____	____	____
<u>Impact</u>			
C. Flooding			
<u>Factors</u>			
1. Decreased flow area in site drainage basin	____	____	____
2. Stream or sewer clogging by erosion of unprotected surfaces or containment structure slope failure	____	____	____
<u>Impact</u>			
D. Air quality			
<u>Factors</u>			
1. Increased exhaust emissions from equipment and vehicles due to:	____	____	____
a. Site preparation	( )	( )	( )
b. Disposal activities	( )	( )	( )
c. D.M. transport	( )	( )	( )

Section B (Continued) Site No. ____

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
D. Air quality (continued)			
2. Dust generation due to:	____	____	____
a. Site preparation	( )	( )	( )
b. Disposal activities	( )	( )	( )
c. D.M. transport (open trucks, etc.)	( )	( )	( )
d. Extended dry periods	( )	( )	( )
e. Prevailing winds	( )	( )	( )
3. Odors associated with:	____	____	____
a. Presence of D.M. (with high moisture and/or organic content) at disposal site	( )	( )	( )
b. D.M. transport	( )	( )	( )
c. Leachate exposed through surface seeps or from leachate collection system	( )	( )	( )
Impact			
E. Wildlife habitat and ecosystem alterations	☐	☐	☐
Factors			
1. Destruction of animal breeding habitat, or foraging areas	____	____	____

Section B (Continued)   Site No. ____

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
E. Wildlife habitat and ecosystem alterations (continued)			
2. Physical blockage of travel routes (barrier creation)	____	____	____
3. Food chain alterations	____	____	____
4. Introduction or attraction of foreign species (by transport and disposal of D.M. containing seeds, spores, organisms, etc.)	____	____	____
Impact			
F. Attraction of vectors (insects or rodents) due to creation of favorable breeding areas	☐	☐	☐
Factors			
1. Improper surface drainage resulting in ponding of water	____	____	____
2. Desiccation cracks or other areas with stagnant water	____	____	____
Impact			
G. Infection of humans, birds, or animals by direct or indirect contact with or ingestion of constituents in D.M.	☐	☐	☐
Factors			
1. Toxic substances spread by contact with or through the food chain	____	____	____

Section B (Continued) Site No. ____

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
G. Infection of humans, birds, or animals by direct or indirect contact with or ingestion of constituents in D.M. (continued)	____	____	____
2. Biomagnification of toxic substances in animals by ingestion of vegetation growing on and aquatic organisms living in D.M.	____	____	____
Impact			
H. Noise	☐	☐	☐
Factors			
1. Site preparation (heavy equipment)	____	____	____
2. Disposal activities (heavy equipment and delivery vehicles)	____	____	____
3. D.M. transport system	____	____	____
Impact			
I. Traffic problems along D.M. transport route	☐	☐	☐
Factors			
1. Accident potential	____	____	____
2. Congestion	____	____	____
3. D.M. spilled	____	____	____

Section B (Continued) Site No. ____

	Anticipated magnitude of impact		
	Very severe	Moderately severe	Less severe
Impact J. Safety hazards	☐	☐	☐
Factors			
1. Potential for site becoming an attractive nuisance	____	____	____
Impact K. Economics in area	☐	☐	☐
Factors			
1. Property devaluation	____	____	____
2. Tax rate alteration	____	____	____
a. Property tax increase	( )	( )	( )
b. Property tax decrease	( )	( )	( )
3. Property damage	____	____	____
Impact L. Alteration of land use in area	☐	☐	☐
Factors			
1. Potential aesthetic degradation due to presence of site and disposal activities	____	____	____
2. Limitation on future site uses due to type of material deposited	____	____	____

M. Comments ____

Section B (Continued) Site No. ____

N. Based on environmental and social impacts, site use for disposal of dredged material would be:

1. Feasible ______

2. Uncertain ______

3. Not feasible ______

V. Assess Public Attitudes Toward This Site

A. Identify appropriate or affected public. Based on past activities in the area and knowledge of similar projects, indicate in the table below which parties can be expected to express interest in the selection of the candidate site.

Section B (Continued) Site No. ____

Group	Name	Address	Telephone no.	Anticipated interest (neg./positive/null)
1. Local & neighborhood residents				
2. Schools				
3. Business interests				
4. Recreation groups				

Section B (Continued) Site No. ____

Group	Name	Address	Telephone no.	Anticipated interest (neg./positive/null)
5. Conservationists	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
6. Active social/ political groups	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
7. Other site users or affected persons	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
8. Other civic groups	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

Section B (Continued)   Site No. ____

B. Identify methods suitable for educating and involving the affected public

1. Public meetings	yes ____	no ____
2. Official hearings	yes ____	no ____
3. Public education programs	yes ____	no ____
4. News media coverage	yes ____	no ____
5. Presentations at special-interest group meetings	yes ____	no ____
6. Other ________________ ________________		

C. Indicate expected or perceived causes for public concern resulting from use of the candidate site for disposal of dredged material

1. Groundwater contamination	yes ____	no ____
2. Surface water contamination	yes ____	no ____
3. Area flooding	yes ____	no ____
4. Vectors & public health hazards	yes ____	no ____
5. Wildlife habitat & ecosystem alterations	yes ____	no ____
6. Air quality degradation	yes ____	no ____
7. Dust	yes ____	no ____
8. Odors	yes ____	no ____
9. Noise	yes ____	no ____
10. Traffic increases	yes ____	no ____
11. Safety hazards	yes ____	no ____
12. Property damage	yes ____	no ____
13. Property devaluation	yes ____	no ____
14. Tax rate alterations	yes ____	no ____
15. Aesthetic degradation	yes ____	no ____
16. Future land use changes	yes ____	no ____
17. Others (e.g., political)____________	yes ____	no ____

D. Evaluate potential effects of public involvement

1. Will public involvement in approving a disposal site cause:

a. Project delays	yes ____	no ____
b. Increased project costs	yes ____	no ____
c. Project rejection	yes ____	no ____

Section B (Continued) Site No. ____

E. Comments ____

____

____

____

F. Based on public attitudes, site use for disposal of dredged material would likely be:

1. Feasible ____
2. Uncertain ____
3. Not feasible ____

VI. Evaluate Economic Factors for This Site

A. Estimate disposal site capital costs

	Item	Unit cost	x	Units	=	Item cost
1.	Land	____		____		____
2.	Access road	____		____		____
3.	Equipment	____		____		____
4.	Facilities & access control	____		____		____
5.	Clearing & grading	____		____		____
6.	Drainage structures	____		____		____
7.	Additional site preparation (e.g., liner placement)	____		____		____
8.	Utility relocation	____		____		____
9.	Environmental monitoring	____		____		____
10.	Structure relocation	____		____		____
11.	Other ____________	____		____		____
	____________	____		____		____
	____________	____		____		____
						____ =

total estimated capital cost

Section B (Continued) Site No. ____

B. Estimated annual site operation and maintenance (O&M) costs (include annual incomes as negative costs - example: sale of material)

Item	Unit cost	x	Units	=	Item cost
1. Equipment O&M	______		______		______
2. Site personnel	______		______		______
3. Monitoring environmental conditions	______		______		______
4. Access road maintenance	______		______		______
5. Facilities upkeep	______		______		______
6. Utilities	______		______		______
7. Other ______________	______		______		______
______________	______		______		______

______ =

total estimated annual O&M cost

C. Estimated annual dredged material transportation costs

Item	Unit cost	x	Units	=	Item cost
1. Loading	______		______		______
2. Transport	______		______		______
3. Unloading	______		______		______
4. Other ______	______		______		______
______________	______		______		______

______ =

total estimated annual transportation cost

Section B (Continued) Site No. ____

D. Estimated future costs after site reaches capacity (include future incomes as negative costs - example: fixed - sale of site; annual - sale of material)

Item	Unit cost	x	Units	=	Item cost
1. Fixed					
a. Site rehabilitation	____		____		____
b. Other (e.g., grading, landscaping)	____		____		____
					____ = total estimated fixed future cost
2. Annual					
a. Continued site monitoring	____		____		____
b. Maintenance	____		____		____
c. Environmental protection facilities	____		____		____
d. Equipment replacement	____		____		____
e. Other____________	____		____		____
________________	____		____		____
					____ = total estimated future annual cost

E. Perform present value analysis on estimated annual and future costs and benefits

1. Years required to fill disposal site to capacity ____________
2. Estimated annual discount rate (%) ______
3. Estimated annual inflation rate (%) ______

Section B (Concluded) Site No. ____

4. Economic values:

   a. ________________________

   b. ________________________

   c. ________________________

   d. ________________________

      1. ________________________

      2. ________________________ = total present value of candidate disposal site

F. Comments ____
____
____
____

G. Based on economic factors, site use for disposal of dredged material would likely be:

   1. Feasible __________

   2. Uncertain __________

   3. Not feasible ________

Section C: Site Acquisition, Preparation, Operation, and Final Use

Site No. ____

290. The final phase of securing and operating a dredged material disposal site involves several steps. Before actual site acquisition, the site must be approved by the various regulatory agencies (i.e., Federal, State, and local). The method of acquiring the site must be determined according to sponsor policy, availability of the site, and owner(s) agreement(s). Implementing disposal activities at a site requires careful preparation for suitable access and a well-designed operating plan which incorporates final site use into the step-by-step operation. This section of the checklist develops the various steps necessary for meeting regulatory agencies' requirements, proper site acquisition, implementation, operating activities, and final use.

I. Coordinate with and Obtain Approval of Jurisdictional Government Agencies

Agency	Approval required	Date solicited	Date obtained
A. Federal (not all agencies listed will have jurisdiction or concern for all disposal sites)	____	____	____
1. Environmental Protection Agency (Washington, D.C. and Regional Office)	____	____	____
2. Department of Interior (Fish & Wildlife, National Park Service, Bureau of Reclamation, Bureau of Land Management)	____	____	____
3. Department of Housing & Urban Development	____	____	____

Section C (Continued) Site No. ____

	Agency	Approval required	Date solicited	Date obtained
4.	Department of Transportation	____	____	____
5.	Department of Health, Education & Welfare	____	____	____
6.	Department of Agri-culture (Soil Conservation Service)	____	____	____
7.	Department of Commerce	____	____	____
8.	Other ____	____	____	____
	____	____	____	____
	____	____	____	____
B.	Regional			
1.	Port Authorities	____	____	____
2.	Coastal Zone Management Commission	____	____	____
3.	River Basin Planning Commission	____	____	____
4.	Land Use Management Group	____	____	____
5.	Council of govern-ments or regional associations	____	____	____
6.	Other ____	____	____	____
	____	____	____	____
	____	____	____	____
C.	State(s)			
1.	Department of Natural Resources, Department of Environmental Protection or equivalent	____	____	____
2.	Water Quality Control Board	____	____	____

Section C (Continued) Site No. ____

	Approval required	Date solicited	Date obtained
3. Department of Solid Waste Management or equivalent	____	____	____
4. Department of Historic & Cultural Affairs or equivalent	____	____	____
5. Department of Education	____	____	____
6. Department of Community Affairs or equivalent	____	____	____
7. Department of Agriculture	____	____	____
8. Bureau of Mines	____	____	____
9. Department of Transportation	____	____	____
10. Other ____	____	____	____
____	____	____	____
____	____	____	____

D. Local (county, township, municipality)

	Approval required	Date solicited	Date obtained
1. Planning Department	____	____	____
2. Public Works (highways, solid waste, water pollution control)	____	____	____
3. Other ____	____	____	____
____	____	____	____
____	____	____	____

E. Comments ____

Section C (Continued) Site No. ____

II. Acquire Site

A. Determine method of site acquisition

Purchase ☐ , Perpetual Easement ☐ ,

Temporary Easement ☐ , Lease ☐ ,

Other ____________________

B. Develop agreements with site owner(s)/sponsor(s)

1. Owner understands intended site use. yes ____ no ____
2. Provisions have been made for site access. yes ____ no ____
3. Length of easement or lease (if site not purchased). ____________________
4. Conditions for termination of agreement: ____________________

   ____
5. Identify parties responsible for:
   - disposal permit fees (if any) ____________________

     ____
   - site operation and maintenance ____________________

     ____
   - postdisposal clean up ____________________
   - postdisposal environmental monitoring ____________________
   - correcting environmental problems that may arise during and/or after site operations ____________________

     ____

C. Comments ____________________

____

____

____

____

Section C (Continued) Site No. ____

III. Determine Requirements for Site Preparation

		Required	Not required
A.	Access road construction	______	______
B.	Removal of vegetation and rocks	______	______
C.	Grading and leveling	______	______
D.	Drainage diversion	______	______
E.	D.M. containment structure design and construction	______	______
F.	Groundwater protection	______	______
G.	Base soil preparation	______	______
H.	Building construction	______	______
I.	Utilities installation	______	______
J.	Utilities relocation	______	______
K.	Building relocation	______	______
L.	Road relocation	______	______
M.	Pipeline relocation	______	______
N.	Access control	______	______
O.	Other ______________________	______	______
	______________________________	______	______
	______________________________	______	______
	______________________________	______	______

P. Comments ____

____

____

____

____

IV. Select Methods for Site Operation

A. Method of receipt and transfer of material from delivery system ______________________________

Section C (Continued) Site No. ____

B. Will a stockpiling area be required? yes ____ no ____

1. Size of area ____________________

2. Location of area ____________________

3. Special subsoil preparation (e.g., liner type) ____________________

C. Method of transferring material from stockpile area to the desired disposal area ____________________

D. Method of spreading and layering material ____________________

Equipment required ____________________

Equipment rental companies (list) ____________________

Other agencies equipment can be obtained from (list) ____________________

E. Monitoring and environmental control program ____________________

Equipment required ____________________

Equipment maintenance required ____________________

F. Comments ____________________

Section C (Concluded) Site No. ____

V. Plan for Disposal Site Closing and Future Site Use

A. Requirements for site closing

1. Final cover material yes ____ no ____
2. Removal of berms yes ____ no ____
3. Dismantle equipment yes ____ no ____
4. Removal of structures yes ____ no ____
5. Grading yes ____ no ____
6. Erosion control yes ____ no ____
7. Landscaping yes ____ no ____
8. Other ____________ yes ____ no ____

____

B. Continued site monitoring and environmental control program ____________

____

C. Future site use plans ____________

____

____

D. Comments ____________

____

____

____

____

REFERENCES

A. D. Little, Inc., "A Feasibility Study of Lawn Sod Production and/or Related Activities on Dredged Material Disposal Sites," Contract Report D-75-1, January 1975, prepared under contract to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Adkins, W. G., and Burke, D., "Social Factors in Highway Decision-Making," Interim Report, October 1971, Texas Transportation Institute, Texas A & M University, College Station, Texas.

American Society of Civil Engineers, "ASCE - Manuals and Reports on Engineering Practice - No. 39, Sanitary Landfill," 1976, Solid Waste Management Committee of the Environmental Engineering Division, Headquarters of the Society, New York, New York.

Baratz, B., "Site Selection Criteria for the Disposal of Dredged Materials," June 1973, U.S. Environmental Protection Agency, Office of Research and Monitoring, Washington, D. C.

Bartos, M. J., Jr., "Classification and Engineering Properties of Dredged Material," Draft Report, 1977a, Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Bartos, M. J., Jr., "Investigation of Using Dredged Material in Solid Waste Management," Draft Report 1977b, Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Berlin, J. A., "Diked Disposal Areas as a Habitat for Mosquitoes," Miscellaneous Paper, September 1976, U. S. Army Engineer District, Buffalo, CE, Buffalo, New York.

Caterpillar Tractor Co., "Caterpillar Performance Handbook," 6th ed., January 1976, CAT Publications, Los Angeles, California.

Chen, K. Y. et al., "Research Study on the Effect of Dispersion, Settling, and Resedimentation on Migration of Chemical Constituents During Open-Water Disposal of Dredged Materials," Contract Report D-76-1, February 1976, prepared by the Environmental Program, University of Southern California, Los Angeles, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Chian, E. S. K., and De Walle, F. B., "Compilation of Methodology for Measuring Pollution Parameters of Landfill Leachates," EPA-600/3-75-011, October 1975, Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, Washington, D. C.

Clark, R. M., and Goddard, H. C., "Relating Socio-Economic Variables to Technology for Environmental Management," 1973, U. S. Environmental Protection Agency, Washington, D. C.

Department of the Army, Office, Chief of Engineers, "Survey Investigations and Reports," Pamphlet No. 1120-2-1, May 1967, Washington, D. C.

Department of the Army, Office, Chief of Engineers, "Investigation, Planning and Development of Water Resources," Circular No. 1120-2-55, September 1970, Washington, D. C.

Department of the Army, Corps of Engineers, "Environmental Guidelines for the Civil Works Program of the Corps of Engineers," IWR Report 70-5, November 1970, Institute for Water Resources, Washington, D. C.

Department of the Army, Office, Chief of Engineers, "The Army Corps of Engineers and Environmental Conservation; 9 Questions," ER1165-2-500, April 1971, Civil Works Directorate, Washington, D. C.

Department of the Army, Office of the Chief of Engineers, "Waste Resources Policies and Authorities," Circular No. 1165-2-100, May 1971, Washington, D. C.

Department of the Army, "Guidelines for Assessment of Economic, Social and Environmental Effects of Civil Works Projects," ER1105-2-240, November 1975, Washington, D. C.

Fenn, D. G., and Hanley, K. J., "Use of the Water Balance Method for Predicting Leachate from Sanitary Landfills," June 1973, Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, Washington, D. C.

Fenn, D. G., Hanley, K. J., and De Geare, T. V., "Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites," EPA/530/SW-168, October 1975, Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, Washington, D. C.

Fungaroli, A. A., "Pollution of Subsurface Water by Sanitary Landfills," Vol. 1, Environmental Protection Publication, SW-12rg, 1971, U.S. Government Printing Office, Washington, D. C.

Fungaroli, A. A., and Steiner, R. L., "Laboratory Study of the Behavior of a Sanitary Landfill," Journal of the Water Pollution Control Federation, Vol. 43, February 1971, p. 252.

Gambrell, R. P., et al., "Transformations of Heavy Metals and Plant Nutrients in Dredged Sediments as Affected by Oxidation Reduction Potential and pH, Vol II, Materials and Methods/Results and Discussion," Contract Report D-77-4, April 1977, prepared by the Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Garbe, C. W., Smith, D. D., and Amerasinghe, Sri, "Demonstration of a Methodology for Dredged Material Reclamation and Drainage," Contract Report D-74-5, September 1974, prepared by Dames & Moore, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Geswein, A. J., "Liners for Land Disposal Sites, An Assessment," Report No. SW-137, 1975, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, Washington, D.C.

Harrison, J. E., and Chisholm, L. C., "Identification of Objectionable Environmental Conditions and Issues Associated with Confined Disposal Areas," Contract Report D-74-4, September 1974, prepared by Arthur D. Little, Inc. under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Harrison, W., et al., "Abatement of Malodors at Confined Dredged Material Disposal Sites," Contract Report D-76-9, August 1976, prepared by Argonne National Laboratory, Argonne, Illinois, for the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Haxo, H. E., Jr., and White, R. M., "Evaluation of Liner Materials Exposed to Leachate, Second Interim Report," EPA-600/2-76-255, September 1976, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Hudson, J. F., et al., "Evaluation of Policy-Related Research in the Field of Municipal Solid Waste Management," Research Report R74-56, September 1974, National Science Foundation, Washington, D. C.

Hughes, G. M., Landon, R. A., and Farvolden, R. N., "Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois," Report No. SW-12d, 1971, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Hunt, J., "Upland Habitat Development on Dredged Material," Draft Report, 1976, Natural Resources Development Branch, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

International Engineering Company, Inc., "Final Report - Engineering Concept Study, Dredge Spoils Disposal Facility, Skaggs Island, California," April 1975, San Francisco, California.

International Working Group on the Abatement and Control of Pollution from Dredging Activities, May 1975, Windsor, Ontario, Canada.

Khalid, R. A., et al., "Transformations of Heavy Metals and Plant Nutrients in Dredged Sediments as Affected by Oxidation Reduction Potential and pH, Vol I, Literature Review," Contract Report D-77-4, April 1977, prepared by the Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Krizek, R. J., et al., "Engineering Characteristics of Polluted Dredgings," Technical Report No. 1, March 1973, Department of Civil Engineering, Northwestern University, Evanston, Illinois.

Krizek, R. J., et al., "Stabilization of Dredged Materials," Technical Report No. 2, September 1974, Department of Civil Engineering, Northwestern University, Evanston, Illinois.

Krizek, R. J., and Salem, A. M., "Behavior of Dredged Materials in Diked Containment Areas," Technical Report No. 5, September 1974, Department of Civil Engineering, Northwestern University, Evanston, Illinois.

Lackey, L. L., "Public Attitude Towards Hazardous Waste Disposal Facilities," 1973, U. S. Environmental Protection Agency, Washington, D. C.

Lee, C. R., Engler, R. M., and Mahloch, J. L., "Land Application of Waste Materials from Dredging, Construction, and Demolition Processes," Miscellaneous Paper D-76-5, June 1976, Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Lee, G. F., and Plumb, R. H., "Literature Review on Research Study for the Development of Dredged Material Disposal Criteria," Contract Report D-74-1, June 1974, prepared by the Institute for Environmental Studies, University of Texas-Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Lee, G. F., et al., "Research Study for the Development of Dredged Material Disposal Criteria," Contract Report D-75-4, November 1975, prepared by the Institute for Environmental Sciences, University of Texas-Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

LeGrand, H. E., "System for Evaluation of Contamination Potential of Some Waste Disposal Sites," Journal of the American Waterworks Association, Vol. 56, No. 7, 1964, p. 959.

Lehr, J. H., et al., "A Manual of Laws, Regulations, and Institutions for Control of Groundwater Pollution," Report No. 440/9-76-006, June 1976, U.S. Environmental Protection Agency, Washington, D.C.

Mann, R., et al., "Landscape Concept Development for Confined Dredged Material Sites," Contract Report D-75-5, December 1975, prepared by Roy Mann Associates, Inc., Cambridge, Massachusetts, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Meyer, G. L., "Hazardous Waste Treatment/Disposal Site Screening/Selection Criteria," In-house Document, 1974, Office of Radiation Programs, U. S. Environmental Protection Agency, Washington, D. C.

Mooij, H., and Eng, P., "Recommended Groundwater and Soil Sampling Procedures: Proceedings of an International Seminar," Solid Waste Management Branch Report EPS-4-EC-76-7, June 1976, Environmental Conservation Directorate, Minister of Supply and Services, Mississauga, Ontario, Canada.

Murphy, W. L., and Zeigler, T. W., "Practices and Problems in the Confinement of Dredged Material in Corps of Engineers Projects," Technical Report D-74-2, May 1974, Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

"National Register of Historical Places," Federal Register, February 29, 1974, Vol. 39, No. 34, pp. 6401-6481.

Office of Noise Abatement and Control, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," Report No. 550/9-74-004, 1974, U. S. Environmental Protection Agency, Washington, D. C.

Office of Noise Abatement and Control, "Noise Source Regulations in State and Local Ordinances," Report No. 550/9-75-020, 1975, U. S. Environmental Protection Agency, Washington, D. C.

Phillips, C. R., and Eng, P., "Development of a Soil-Waste Interaction Matrix," Solid Waste Management Report EPS 4-EC-76-10, October 1976, Environmental Conservation Directorate, Minister of Supply and Services, Mississauga, Ontario, Canada.

Phillips, C. R., Eng, P., and Nathwani, J., "Soil-Waste Interactions: A State-of-the-Art Review," Solid Waste Management Report EPS 3-EC-76-14, October 1976, Environmental Conservation Directorate, Minister of Supply and Services, Mississauga, Ontario, Canada.

Qasim, S. R., and Burchinal, J. C., "Leaching of Pollutants from Refuse Beds," Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 96, No. SA1, February 1970, pp. 49-58.

Remson, I., et al., "Water Movement in an Unsaturated Sanitary Landfill," Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 94, April 1968, p. 307.

Salvato, J. A., et al., "Sanitary Landfill - Leaching Prevention and Control," Journal of the Water Pollution Control Federation, Vol. 43, No. 10, October 1971, pp. 2084-2100.

SCS Engineers, "Description and Findings of Study of Sewage Treatment Solids Disposal by Subsoil Land Application, Volume 1," Draft Final Report, January 1976, Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, Washington, D. C.

SCS Engineers, "The Selection and Monitoring of Land Disposal Case Study Sites, Volumes 1 through 3," Draft Final Report, May 1976, Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, Washington, D. C.

Sendlein, L. V. A., and Palmquist, R. C., "A Topographic-Hydrogeologic Model for Solid Waste Landfill Siting," Groundwater, Vol. 12, May/June 1975, pp. 261-267.

Shimp, N. F., "Investigation of Leachate Pollution Attenuation in Soils," April 1973, Illinois State Geological Survey, Urbana, Illinois.

Skjei, S. S., "Socioeconomic Aspects of Dredged Material Disposal: the Creation of Recreation Land in Urban Areas," Contract Report D-76-6, May 1976, prepared by the Department of Environmental Sciences, University of Virginia, for the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Smith, D. D., "New Federal Regulations for Dredged and Fill Material," Environmental Science and Technology, Vol. 10, April 1976, pp. 328-333.

Souder, P. S., et al., "Dredged Material Transport Systems for Inland Disposal and/or Productive Use Concepts," Working Draft, 1976, prepared by General Research Corp., McLean, Virginia under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

State of California, "The Regulation of Dredging," January 1976, San Francisco Bay Conservation and Development Commission, San Francisco, California.

Stearns, R. P., et al., "Oil Spill: Decisions for Debris Disposal, Volume I, Procedures Manual," Draft Final Report, August 1976, Oil and Hazardous Materials Spill Branch, U. S. Environmental Protection Agency, Edison, New Jersey.

U. S. Army Engineer District, Chicago, "Design Analysis, Lucas-Berg Disposal Area, Worth, Illinois," March 1977a, Chicago, Illinois.

U. S. Army Engineer District, Chicago, "Specifications for Lucas-Berg Disposal Site South Increment at Worth, Illinois," January 1977b, Chicago, Illinois.

U. S. Army Engineer District, San Francisco, "Land Disposal of Dredged Material and Economic Comparison of Alternative Disposal Systems, Dredged Disposal Study San Francisco Bay and Estuary: Appendix J, Land Disposal," October 1974, San Francisco, California.

U. S. Department of Commerce, "Untangling Dredging Regulations," June 1976, Maritime Administration, San Francisco, California.

U. S. Department of the Interior, "United States List of Endangered Fauna," Fish and Wildlife Service, 1974, Government Printing Office, Washington, D. C.

U. S. Environmental Protection Agency, "Don't Leave It All to the Experts: The Citizen's Role in Environmental Decision Making," November 1972a, U. S. Government Printing Office, Washington, D. C.

U. S. Environmental Protection Agency, "Chapter I, Suggested Guidelines for Public Participation," Title 40-Protection of Environment (draft), November 1972b, Washington, D. C.

U. S. Environmental Protection Agency, "Summary Report: Municipal Solid Waste Generated Gas and Leachate," Review Draft, 1974a, Disposal Branch, Solid and Hazardous Waste Research Laboratory, Cincinnati, Ohio.

U. S. Environmental Protection Agency, "Thermal Processing and Land Disposal of Solid Wastes Guidelines," CFR 40:240.202, Federal Register, Vol. 39, No. 158, August 14, 1974b, p. 29331.

U. S. Environmental Protection Agency, "Dredge Spoil Disposal Criteria," Draft Report, 1975a, EPA Region IX, San Francisco, California.

U. S. Environmental Protection Agency, "Evaluation of Land Application Systems: Evaluation Checklist and Supporting Commentary," Technical Bulletin, EPA 430/9-75-001, March 1975b, Washington, D. C.

U. S. Environmental Protection Agency, "Navigable Waters: Discharge of Dredged and Fill Material," Federal Register, Vol. 40, No. 173, September 5, 1975c, p. 41292.

U. S. Environmental Protection Agency, "Hazardous Waste Landfill Site Screening Criteria," Guidance Document, Preliminary Draft, 1976, Office of Solid Waste Management Programs, Washington, D. C.

Wakeford, R. C., and Macdonald, D., "Legal, Policy, and Institutional Constraints Associated with Dredged Material Marketing and Land Enhancement," Contract Report D-74-7, December 1974, prepared by American Technical Assistance Corporation, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

SCS Engineers, Long Beach, Calif.

Feasibility of inland disposal of dewatered dredged material: A literature review / by SCS Engineers, Long Beach, California. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.

153 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-33)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract No. DACW39-76-C-0121 (DMRP Work Unit No. 3B02)

References: p. 147-153.

1. Dewatering. 2. Disposal areas. 3. Dredged material disposal. 4. Inland disposal sites. 5. Site selection. 6. Solid wastes. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-33.

TA7.W34 no.D-77-33

78